SCIENCE EDUCATION

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N. Eldred Bingham

Associate Professor of Science Education, Northwestern University, Evanston, Ill.

PRESIDENT OF NARST

DOCTOR N. Eldred Bingham, Associate Professor of Science Education at Northwestern University, Evanston, Illinois, was elected President of the National Association for Research in Science Teaching at the annual business meeting in New York City, February 13, 1949. He succeeds Dr. Joe Young West of the State Teachers College, Towson, Maryland.

Dr. Bingham was born in Edinburg, Ohio, on June 7, 1901. His undergraduate college work includes Hiram College, Hiram, Ohio, 1919–1920; B.S. Ohio State University, 1923; B.S. Kent State University, 1926. Professional and Graduate School work was done at Columbia University where he received an M.A. degree in 1930 and a Ph.D. degree in 1938.

Teaching experience includes: Assistant principal and science teacher at Edinburg High School 1923–1925; Assistant principal and science teacher at Paris Township High School, Wayland, 1925–26; Principal and Science Critic Teacher, Hiram High School and Hiram College, 1926–29; Instructor in the New Jersey State Teachers College, Montclair, New Jersey, 1929–32; Instructor in Lincoln School Teachers College, Columbia University, 1932–43; Instructor in the Horace Mann-Lincoln Institute of School Experimentation, Teachers College, Columbia University, 1943–44; Headmaster. Oak Lane Country Day School of Temple University and Associate Professor of Education, 1944–45; Associate Professor of Science Education, Northwestern University since 1945. Summer school teaching includes Teachers College of Columbia University, Kent State University, and Penn State College.

Dr. Bingham is a member of Kappa Delta Pi, Phi Delta Kappa, Alpha Zeta, American Association for the Advancement of Science, National Council on Elementary Science, and the National Association for Research in Science Teaching.

Dr. Bingham's publications include articles in *Science Education, Teachers College Record, Scientific Monthly, Clearing House, The American Biology Teacher, The Science Classroom,* and *The Teaching Biologist.* He is co-author of the widely known and popular high school biology textbook *Biology and Man* published by Ginn and Company.

Dr. Bingham's present research interests relate to those methods of education which induce individuals to use the methods of science in their daily thinking, regardless of age.

Nationally known and admired in the field of science education, Dr. Bingham is characterized by a true scientific attitude in his respect for the opinions and attitudes of not only co-workers in his own field but those engaged in other areas of endeavor.

Thus Dr. Bingham brings to the presidency of The National Association for Research in Science Teaching a background of practical experience and leadership that has characterized his predecessors in that office. Under his dynamic leadership the organization has every promise of having a year of outstanding accomplishments.

PROGRESS REPORT OF THE COMMITTEE ON RESEARCH IN JUNIOR-COLLEGE SCIENCE *

THIS COMMITTEE on Research in Junior-College Science was constituted in 1947 and was charged with investigating the status of science courses at the junior-college level which were devoted to general education objectives. This problem was investigated during 1947 by means of an informal inquiry sent to a large number of representative two-year and four-year institutions. The results of this inquiry were reported at the meeting of the NARST in Atlantic City in February, 1948. At that

* W. C. Van Deventer, Chairman, for the Committee on Research in Junior-College Science, National Association for Research in Science Teaching.

time it was decided that the further work of the committee should consist of an investigation of typical courses at selected institutions, which would serve to illustrate specific approaches to the problems of general education college science teaching.

During the year Mr. Robert A. Bullington, student at Northwestern University, a member of the committee, carried on an extensive investigation of general education college science courses, as a basis for preparation of a doctor's dissertation, under the direction of Dr. N. E. Bingham. Mr. Bullington's investigation was aided and supported by the Cooperative Committee of the American Association for the Advancement of Science under the chairmanship of Dr. K. Lark-Horowitz of Purdue University. Our committee cooperated with the AAAS committee and Dr. Bingham in laying the groundwork for Mr. Bullington's investigation.

During the current year also, Dean E. J. McGrath then at the University of Iowa published a monograph entitled "Science in General Education" consisting of descriptions of typical general education science courses at the college level. This work was carried on independently of the committee, but two members of the committee and one other institution represented on the committee contributed to it.

Because of these developments the committee deemed it best to conduct no specific investigations of its own during 1948. However, at this time the committee feels that two reports should be presented to the members of the N.A.R.S.T. One of these is a preliminary report by Mr. Bullington on his thesis investigation. For this we wish to acknowledge indebtedness to Dr. N. E. Bingham and Dr. K. Lark-Horowitz for their permission to include it. The other is in the form of a critical evaluation of general education college science teaching, based on the McGrath monograph, Mr. Billington's investigation, and the experiences and investigations of other members of the committee during the past two years.

Vaden Miles
Charles W. Reynolds
Edward K. Weaver
Oliver S. Loud
Philip N. Powers
Robert A. Bullington
Mervin E. Oakes
W. C. Van Deventer, *Chairman*

REPORT OF THE COMMITTEE ON RESEARCH IN THE TEACHING OF SCIENCE

The Committee on Research in the Teaching of Science formulated plans for its activities in a two-day meeting with the Specialist for Science in the U. S. Office of Education, Washington, D. C., in June, 1947. The work was subsequently carried on chiefly by correspondence. At the joint conference of the science-teacher organizations at Washington, D. C., in December, 1948, four members of the Committee, together with a few other members of the NARST, held a breakfast meeting and a luncheon meeting at which further policies and activities were planned. The proposals stated below were formulated in those meetings and are herewith presented to the Association for study, revision if necessary, and action. The Committee will take steps to initiate, guide, and implement those proposals that are approved by the Association.

It is proposed

(1) That the Specialists for Science in the Office of Education be requested to ascertain by appropriate means the institutions which are actively directing Masters' and Doctors' theses in the teaching of science.

(2) That the Committee attempt to ascertain from bureaus of research in colleges,

universities, and school systems which ones would be willing to consider directing and/or pursuing research projects in the teaching of science.

(3) That members of the Committee select from among the research investigations which have been published, those worthy of being digested for dissemination. Two types of digests are deemed essential: those of the type which have appeared from time to time in *Science Education* and which are intended for the scholars in the field; and non-technical interpretations of the findings and implications of such research investigations, which are planned for those not primarily interested in research techniques.

(4) That the Committee devise a blank to serve both for reporting research in progress and for suggesting other needed research in the teaching of science at the Master's and Doctor's levels; and that the Committee arrange to use this blank annually or oftener for obtaining the desired information from Directors of Research in science education in colleges, universities, and other institutions and agencies.

(5) That the members of the Committee on Research, members of the NARST and others whose help may be enlisted, be requested to send, annually or oftener, to the Chairman of the Committee on Research or to its Secretary (who may be designated later), the titles and brief abstracts of Masters' and Doctors' theses which have been completed during certain years (to be specified later). It is planned to make both edited lists of these titles and edited abstracts thus obtained, available to all members of the NARST and to other leaders in science education.

(6) That the NARST include in its budget an item to cover the costs of preparing materials and providing necessary postage, and to cover other incidental expenses resulting from the carrying out of these proposals.

(7) That the members of the Committee do their utmost to secure from various foundations grants of money for needed research in science education.

(8) That the Committee be authorized to select a Secretary who shall assist in appropriate ways, in carrying out the foregoing proposals.

FRANCIS D. CURTIS, *Chairman*
ARTHUR O. BAKER
G. P. CAHOON
EARL R. GLENN
M. O. PELLA
WILLIAM C. VAN DEVENTER

SURVEY OF INVESTIGATIONS IN JUNIOR HIGH-SCHOOL SCIENCE:

PROGRESS REPORT OF THE COMMITTEE ON RESEARCH IN JUNIOR HIGH-SCHOOL SCIENCE *

I. INTRODUCTION

DURING the year 1948 the Junior High-School Committee has engaged in the following activities:

1. The proposals for needed investigations as reported at the 1947 meeting in Atlantic City have received further attention as to possibilities of restatement and extension. These investigations were first summarized in *Science Education*, Volume 32, April, 1948, pages 175–185.

2. The theses and dissertations as given in the 1947 report and distributed at the Atlantic City meeting have been classified under the institutions in which the work was done. As a result of extensive corre-

* For the Committee by, Earl R. Glenn, Chairman of the Committee on Research in Junior High-School Science, National Association for Research in Science Teaching.

spondence by the chairman during 1948, about twenty-five individuals have volunteered to serve on the committee during 1949 and 1950 if necessary. The chief project proposed for 1949 involves the preparation of abstracts for about three hundred unpublished manuscripts.

3. At an early stage in the activities of the Junior High-School Committee a group of science teachers in the Cleveland area organized themselves under the chairmanship of Mr. Arthur O. Baker to consider a limited number of problems of science education in grades seven, eight and nine. The work of this local committee is to be continued during 1949.

4. At the New York meeting of NARST the following members of the Committee participated in an informal conference on the plans for work during 1949. Those present were:

Dr. Kenneth E. Anderson
University of Kansas
Lawrence, Kansas

Dr. Richard R. Armacost
Syracuse University
Syracuse 10, New York

Dr. Paul F. Brandwein
Forest Hills High School
Forest Hills, L. I., New York

Miss Archie J. MacLean
Supervisor, Science Education Section
Room 314, 1205 Pico Blvd.
Los Angeles 15, California

Alfred D. Beck
Division of Junior High Schools
110 Livingston St., Brooklyn, N. Y.

Dr. George G. Mallinson
Western Michigan College of Education
Kalamazoo 45, Michigan

Dr. John G. Read
Boston University, School of Education
84 Exeter St., Boston 16, Mass.

Dr. Raymond L. Walter
Plymouth Teachers College
Plymouth, New Hampshire

Dr. Herbert S. Zim
64 Reid Avenue
Port Washington, L. I., New York

The chairman invited Dr. Philip G. Johnson and Mr. Robert H. Carleton to attend this session and take part in this policy-making discussion. We greatly appreciate their interest in the work of the committee.

5. Several proposals were approved by the committee members present at the New York meeting. These were later presented to the business session of The National Association for Research in Science Teaching. Formal action on these proposals on the work of the committee will appear in the minutes of the business session of the association.

II. SOME NEEDED INVESTIGATIONS

It was the original intention of the committee to prepare a list of specific investigations which by general agreement are in need of attention in various graduate schools. This list was to have been distributed in colleges and universities where graduate students in science education are expected to write theses. As the discussion of the 1947 proposals continued during the year 1948 it became increasingly apparent that until the committee had made an exhaustive survey of both the published and unpublished investigations in junior high-school science no appropriate list of needed researches could be prepared with any confidence. Therefore, the revision of the proposals in the 1947 report was not carried to completion. In the meantime the committee has directed its attention to a survey of about three hundred manuscripts on general science that have been found in various college and university libraries.

III. PROGRAM OF THE COMMITTEE FOR 1949

After extensive correspondence during the past year and detailed discussion at the New York meeting the committee has decided to concentrate its attention on the unpublished manuscripts dealing with general science in grades seven, eight, and nine. A partial bibliography of these manuscripts has been compiled. These titles have been classified according to the institutions in which the work was done. About 250 such manuscripts are given in the list below. The members of the committee expect to secure copies of these theses from the colleges and universities or The Library of

the U. S. Office of Education. In some cases it may be necessary to write to the authors themselves. We are certain now as to the difficulties we shall encounter in securing the manuscripts for review. So far as known such a large bibliographical project in this field has not been undertaken in previous years. At the 1950 meeting of the association we expect to have accurate information on the availability of these unpublished manuscripts.

Assignments have been made to individual members of the committee. It is expected that a diligent search will be conducted to discover additional colleges and universities that grant advanced degrees and require the preparation of a thesis or a dissertation. The partial list of manuscripts given below will undoubtedly be greatly extended as the members of the committee have an opportunity to survey the institutions in their respective states. Miss MacLean has just completed some preliminary work for the committee in searching the files of the University of Southern California and the University of California at Los Angeles. This survey reveals sixteen new titles in these two institutions. It is expected that other new titles will be revealed by the surveys of various states which will be made by the committee during 1949, for the school years of 1940 to 1949. We have no information for these years at present. The preliminary work will involve the manuscripts given in the following list:

A PARTIAL BIBLIOGRAPHY OF UNPUBLISHED THESES AND DISSERTATIONS. 1928–1940

(This list is compiled from "Research Studies in Education" The Library Division, U. S. Office of Education)

Boston University
Clish, Albert R.
Giovannangeli, Arthur J.
Riccio, Angelo Pasquale
Richardson, Evan Carleton
Smith, Eleanor Marrian

Boston College
DiMattia, Angelo Anthony
Lynch, Thomas Joseph
Murray, John Joseph

Bridgewater
Bronspiegel, Philip

Brown
Daily, Bertha Isabel
Easan, Mary R.
Steere, Ruth Graves

Bucknell University
Gilmore, L. P.

Chicago
Gorman, Harriet Ann
Woods, Leila Glaphyra

Cincinnati
Bradbury, Bernard S.
Harrison, Everett S.
Lampkin, Richard H., Jr.

College of the City of New York
Berlin, Herman
Leibson, B. M.
Schiffman, David
Taplitz, Benjamin M.

Colorado State Teachers College
Barnard, John D.
Geyer, Warren Francis
Selberg, Edith

Columbia
Brock, Lillian A.
Eldredge, William L.
Heiss, Elwood D.
MacKay, Minnette

Creighton
Henderson, Charles

Detroit
Wilson, Della Hastings

Drake
Fox, Virgil
Slotten, R. M.

Duke
Swearingen, Mildred
Terry, C. E.

East Texas State Teachers College
Gray, Hugh C.

Emory
Adams, Edward L.

Fitchburg
Hannigan, Elizabeth A.

Illinois
Barr, Dwight Franklin
Cockrun, A. E.
Heath, A. W.

Indiana State Teachers College
Branstetter, H. Warren
Bratt, Elliott C.
Harris, Ralph W.
Hensley, Russell W.
Schauss, Mabel

Johns Hopkins
Joseph, Rosina C.

Kansas State College
Johnson, A.

Kansas State Teachers College
Baker, Bessie M.
Broadlick, J. N.
Elliott, W. H.
Hainline, A. O.
O'Leary, Vincent Charles
Richmond, Frances Churchill
Wolfenbarger, O. K.

Kentucky
Graham, Charles C.
King, Virgil Doyle

Louisiana State
Crowley, Cecil Carl
Davies, Mary Thompson
McKneely, Grace T.
Slocum, J. S.
Stark, M. Janet
Strickler, George Marion

Louisville
Burlingame, Mrs. Paul

Loyola University
Bek, Cornelius Frederick

Massachusetts State College
Gruner, Saul G.

Michigan
Adams, Paul Lorne
Anderson, Wendell H.
Bickel, John C.
Cruikshank, James
Curtis, Francis D.
Dykhouse, C. J. and Curtis, Francis D.
Farnum, Don E.
Forbush, Keith C.
Forsyth, Kenneth E.
Grophear, Herman
Hobart, Calvin Romain
Moore, F. W.
Smith, James Warren
Stone, Leon E.
Southwell, Cash J.
Vicklund, O. W.
Weinstock, Charles
Wilber, Oliver

New York State College for Teachers
Gugino, Peter Ross
Hepinstall, James Thomas

New York
Barnes, Cyrus W.
Boretz, Nettae
Markle, Charles Joseph
Martin, Robert William

North Texas State Teachers College
Neely, Thomas Oran

Notre Dame
Kannally, Sister M. Richard

The Ohio State University
Beery, Ralph D.
Bixler, Melvin R.
Chapman, Gerald Howard
Conn, R. D.
Jones, Claren Corwin
Heitz, George C.
Kidwell, Arden A.
Kirkland, Arthur William
Loudin, Harold Hugh
Powers, Stuart C.
Rhoades, Levi F., Jr.
Shaffer, Arthur B.
Taylor, Donald T.
Thomas, James Luther

Oklahoma A. and M. College
Anderson, Ted C.
McKinney, George Tempel

Peabody
Adams, Homer
Gill, Anna K.
Green, Ollie
Hollandsworth, James G.
Killebrew, William B.
Redford, Alta Lindsay
Reynolds, Charles William

Colorado
Berg, Theodore R.
Hale, John Elden
Howard, Lester R.
Moore, John E.
O'Neill, Richard Wallace
Shuller, Albert Theodore
Williams, Arthur V.
Word, Aubrey Hugh

Hawaii
Nakagawa, Shizuko

Idaho
Eckermann, Agnes Clara

Iowa
Beard, Burrus Everett
Dunlop, John
Foster, Richard James
Hack, Walter
Hankamp, Gertrude
Harris, Russia
Heacock, Elmer V.
Helt, Raymond L.
Huffman, Oscar T.
Ingraham, John R.
Lannholm, Gerald V.
Latimer, Orion P.
LeCocq, C. Louis
Littelle, Glenn P.
Matteson, Harvey D.
Metier, Ardath R.
Miller, Earl A.
Milenberg, Marcus C.
Norvell, Paul C.
Pfeiffer, Harrison Sumner
Phelps, Maurice Roy
Propst, Otis H.
Rutherford, John LeRoy
Turner, Paul M.
Vander Ploeg, Edward P.
Wallace, L. Dean
Williamson, Charles Brainerd
Zeigler, Robert Terry

Kansas
Riedel, F. A. and Rule, H. C.
Minnesota
Douglass, Harl R. and Peterson, George W.
Floyd, Oliver R.
Peterson, George W.
Rodean, William A.
Smith, Victor Clyde
Nebraska
Bauman, E. K.
Bozchult, Inex and Bozchult, M. K.
McMullen, Warren Anthony
New Hampshire
Bailey, Thomas C.
North Dakota
Koehnlien, Henry Harold
Overn, A. V.
Pennsylvania State College
Butler, Warren N.
Carlson, E. Ross
Remaley, J. W. C.
Singleton, Harry Chamberlain
Wilhowson, C. G.
Pennsylvania
Benner, Gladys Vera
Lower, George G.
Saulter, Charles R.
Peru State Teachers College
Maxwell, Paul A.
Pittsburgh
Coulter, Sara Eleanor
Dorris, Alice K.
Eicher, James Eugene
Gillen, F. Gardner
Hester, Kathleen Beatrice
Houghton, Glenn Hovis
Minister, J. Edward
Rohrbach, Q. A.
Smith, Mae Weber
Squires, Howard G.
Tate, Pearl June
Purdue
Bryant, Dora K.
South Carolina
Lyles, Edith Eliza
Southern California
Carter, George Henry
Dirks, Henry Bertram
Dysart, Russell D.
Gothard, Owen Lee
Griffeath, Matt Russell
Langworthy, Ray Stanley
McKnelly, Cal
Monia, Lillian Irene
Ritchie, Charles Martin
Waldo, Raymond Brown
Weaver, Ruth Perkins
Whittier, Grace A.
Wright, Clifford Allen
Stanford
Buchser, Herman Robert
Kohner, Herbert Walter
Syracuse
Dahl, Alfred H.
Mosher, Florence
Temple
Adams, Harper E.
Barish, William
Billson, Ruth
Snyderman, Isadore L.
Stanley, Frances G.
Tennessee
Grooms, Gordon A.
Hartin, Fred
Johnston, Thomas Nash
Wade, Thomas S.
Texas
Brock, William Hubert
Jordan, Albert Tate
Kelley, Mary Annie Grace
Pollan, William David
Texas College of Arts and Inds.
Agnew, Letha Alice
Toledo
Archambo, Frank C.
Virginia
Fitzhugh, Oscar Garth
Virginia Polytechnic Institute
Kinnear, D. L.
Washington
Klegman, Milton Aaron
Russell, Mae Eleese
Western Reserve
Martin, Earl F.
Wisconsin
Buell, Francis C.
Davis, Ira C.
English, Donald John
Kesler, H. A. W.
Kuemmerlein, Theodore
Whittenberg College
Baker, W. Kenneth
Gossard, Carson F.
Stooksberry, Ross W.
Van Ness, George H.
Yale
McGee, Joseph Arthur

In planning for this review of unpublished manuscripts it has been clear from the early discussions that only a limited number of titles could be assigned each member of the committee if, with the heavy teaching schedules of teachers, the abstracts were to be completed in any reasonable length of time. As a result of several informal conferences we estimated that ten to fifteen manuscripts might be the maximum assignment for each individual. It became necessary then for the chairman to search for about twenty-five volunteers to under-

take this project for the association. As a result of many personal conferences and extensive correspondence over the past year and a half we are able to announce the committee as given below. These specialists have agreed to make this survey during the year 1949 or to continue the work during 1950 if it becomes necessary. The chairman wishes to take this opportunity to express his very great appreciation for the fine spirit of cooperation which has been shown by the individuals listed as the Junior High-School Research Committee which follows:

H. J. Edward Ahrens
3717 Livingston Drive
Long Beach 3, California

Dr. Kenneth E. Anderson
University of Kansas
Lawrence, Kansas

Dr. Richard R. Armacost
Syracuse University
Syracuse 10, New York

Arthur O. Baker
Cleveland Board of Education
Cleveland, Ohio

Alfred D. Beck
Division of Junior High Schools (New York City)
110 Livingston St., Brooklyn, N. Y.

Paul E. Blackwood
Federal Security Agency
U. S. Office of Education
Washington 25, D. C.

Dr. Paul F. Brandwein
Forest Hills High School
Forest Hills, L. I., New York

Dr. Warren P. Everote
Encyclopedia Britannica Films, Inc.
Wilmette, Illinois

Miss Archie J. MacLean
Supervisor, Science Education Section
Room 314, 1205 Pico Blvd.
Los Angeles 15, California

Dr. George G. Mallinson
Western Michigan College of Education
Kalamazoo 45, Michigan

Dr. Victor H. Noll
Michigan State College
East Lansing, Michigan

Dr. Milton O. Pella
University High School
University of Wisconsin
Madison, Wisconsin

Frederick A. Rantz
Director of Science
810 Dexter Avenue
Seattle 9, Washington

Dr. John G. Read
Boston University, School of Education
84 Exeter St., Boston 16, Mass.

Dr. John S. Richardson
College of Education
The Ohio State University
Columbus, Ohio

Mrs. Gjertrud H. Smith
Junior High School Division
451 North Hill St., Los Angeles 12, California

Dr. Victor C. Smith
Ramsey Junior High School
2300 Nicollet Ave.
Minneapolis, Minnesota

John Verrill
University of Minnesota
Duluth Branch
Duluth 5, Minnesota

Dr. Raymond L. Walter
Plymouth Teachers College
Plymouth, New Hampshire

Alton Yarian
Emerson Junior High School
Clifton Blvd. and Jackson Ave.
Lakewood, Ohio

Dr. Herbert S. Zim
64 Reid Avenue
Port Washington, L. I., New York

Earl R. Glenn, Chairman
Box 22
Upper Montclair, New Jersey

At the 1948 convention of the National Education Association in Cleveland several members of the committee discussed proposals for the preparation of abstracts of unpublished manuscripts dealing with general science. During the past several months many letters have been exchanged on the most suitable printed form for these abstracts. Final decisions on this form are yet to be reached but two proposed forms are shown below. One was prepared by Dr. Mallinson; the other by Dr. Victor C. Smith. The members of the committee who participated in the conference at the New York meeting are in rather general agreement that the proposals of Dr. Mallinson and Dr. Smith are suitable for the printed

form to be used. The chairman or any individuals on the committee will be glad to receive suggestions from members of the association or readers of *Science Education* on the most useful form for abstracts or on the policies to be used in reviewing the manuscripts. The two proposed forms are listed below. These will be arranged in final form in the near future.

A. PROPOSED FORM FOR ABSTRACTING UNPUBLISHED SCIENCE INVESTIGATIONS

(By George G. Mallinson)

1. Author .....
   Last First Middle
2. Exact Title of Study.....
3. Institution Where Written.....
4. Degree For Which Submitted.....
5. Data Accepted .....
6. No. of Pages.....
7. Problem As Stated In Study (Be Exact)....
8. Hypotheses Formulated, If Any.....
9. Procedures Used for Collecting Data: (Should state type of study, such as Documentary Analysis, Questionnaire, Interview, Use of Experimental Groups, etc. Should State Number of Publications Analyzed, Number of Questionnaires Sent Out and Returned, Number of Persons Used in Study, Manner of Equating Groups, etc. State reasons given for selecting particular manner of collecting data, and means used for constructing and validating questionnaire. Include any other information you deem pertinent.)
10. Compilation, Analysis and Interpretation of Data:
    a. Describe Charts, Tables, or Other Means Used for Compiling Data
    d. Describe Statistical Measures Used for Analyzing Data.
    (i.e: Mean, Median, Standard Deviation, Coefficient of Correlation, Analysis of Variance and Co-variance, Critical Ratio, Fisher's "t", Chi Square, or any other.)
    c. How Was The Compiled Data Interpreted? (i.e., Extent of correlations, Significances of Difference, etc.)
11. What Conclusions Were Drawn, What Inferences Made, and/or What Implications and Applications Made? Quote Brief Passages If Possible.
12. What Weaknesses Are Evident in the Study? (i.e., Faulty Technique, Inadequate Evidence, Incorrect Statistical Procedure, Unsupported Conclusions.)

B. PROPOSED FORM FOR ABSTRACTING UNPUBLISHED SCIENCE INVESTIGATIONS

(By Victor C. Smith)

Author ..... Institution.....
Title .....
Publication.... Degree.... Date.... Pages....
Type of study (one of the 13 classifications)....
Statement of problem.....
Hypotheses tested .....
Number and kind of subjects used.....
Type of sampling: Total Field, selected, random, matched, or .....
Method of evaluating data:.....
Report of method and results:.....
Conclusions: .....
Limitations of study:.....

IV. THE CLEVELAND COOPERATING COMMITTEE

It is rather generally known that the science teachers of Cleveland have done an outstanding piece of curriculum research in developing a suitable science program for the elementary grades. A few months before the Atlantic City meeting of the Association in 1948 the chairman of the Junior High-School Committee received a communication from Mr. Arthur O. Baker and a group of twenty science specialists in the Cleveland area. This group proposed that the Committee of NARST work with them on a limited range of studies involved in determining a suitable selection of problems for science classes in grades seven, eight, and nine. The chairman has had several conferences with Mr. Baker and other members of this local committee. The Cleveland teachers wish to concentrate their attention on such investigations as are involved in determining more valid criteria for the selection of subject-matter for a particular level of student ability. Several proposals are now receiving attention. At the end of the present school year it is expected that several members of the Junior High-School Committee will meet with the Cleveland group for intensive discussion of this cooperative project. The teachers who are working with the NARST committee from the Cleveland area are listed below. The chairman wishes to express his appre-

ciation for the fine spirit of cooperation shown by Mr. Baker's committee:

THE CLEVELAND COOPERATING COMMITTEE

James C. Adell, Chief, Bureau of Educational Research, Cleveland Board of Education
Grace C. Maddux, Assistant Supervisor of Science, Cleveland Board of Education
Anna E. Burgess, Directing Principal, Cleveland Board of Education
Viola Neuman, Principal, Miles Standish School, Cleveland
Franklin R. Bemisderfer, Principal, Brownell Junior High School, Cleveland
Donald Lentz, Principal, Parma High School, Parma
Olive Klaus, Science Instructor, Ridge Road Junior High School, Parma
J. Paul Visscher, Professor of Biology, Western Reserve University, Cleveland
Donald Dean, Science Instructor, Baldwin Wallace College, Berea
James W. Gebhart, Science Instructor, Euclid Shore High School, Euclid
Robert Finlay, Conservation Instructor, John Marshall High School, Cleveland
Paul R. Young, Supervisor of School Gardens, Cleveland Board of Education
Ellis Persing, Science Instructor, West Technical High School, Cleveland
Ben Levine, In Charge of Science Broadcasts, Radio Station WBOE, Cleveland Board of Education
Ruth Hubbard, Elementary Science Supervisor, Cleveland Heights Board of Education
Alton Yarian, Science Instructor, Emerson Junior High School, Lakewood
Marion Schutler, Elementary Curriculum, Roosevelt School, Lakewood
Alfred Stoddard Jones, Science Instructor, Shaker Heights High School, Shaker Heights, Ohio
J. C. Langmead, Science Instructor, Cleveland Heights High School, Cleveland Heights, Ohio
Clifford Owens, Principal, Euclid Central High School, Euclid, Ohio

Arthur O. Baker, Chairman
Directing Supervisor of Science
Cleveland Board of Education

V. THE COMMITTEE REQUESTS FORMAL APPROVAL FOR THE 1949 PROGRAM

Finally, after two years of preliminary work the committee wishes to present to the National Association for Research in Science Teaching four proposals which constitute the program for the work of the committee for 1949 and possibly 1950. These proposals are listed below:

A PROPOSAL FROM THE COMMITTEE TO THE ASSOCIATION MADE AT THE ANNUAL BUSINESS MEETING, NEW YORK, FEBRUARY 13, 1949

The Junior High-School Science Research Committee of the association wishes to be authorized to carry forward its work by seeking formal approval of the following items:

1. We wish to have the committee, whose names are attached, authorized to continue work during the year 1949 and 1950 if the projects now in progress are not completed at an earlier date. Authority is requested, also, to enlarge the committee to 30 members if the work to be done requires this assistance.

2. We wish to print stationery listing the members of the committee. This stationery is to be used by individuals in correspondence with college and university libraries. It is anticipated that there will be correspondence with some authors of unpublished manuscripts and with The Library of the U. S. Office of Education.

3. We wish to print a suitable blank form for the use of committee members in preparing abstracts of unpublished theses and dissertations as listed in the two attached manuscripts.

4. Finally, the committee wishes authorization to spend 250 dollars for the items listed above and for postage and such other mailing expenses as are involved in the total program of the committee during the year 1949. At the annual meeting in 1950 the committee will make a final report on all expenses involved in the work for the year 1949.

We ask for formal action on this proposal by the National Association for Research in Science Teaching.

BIBLIOGRAPHY OF PROMISING PRACTICES IN PROBLEM-SOLVING AT THE SECONDARY-SCHOOL LEVEL *

It appears from a survey of the literature in this field that evidences of promising practices in problem-solving can be found in three places, namely, 1. where core courses are being experimented with, 2. where source units are being developed in terms of personal and social needs, and 3. among research studies in science education.

Ahrens, H. J. Edward III. *An Investigation and Analysis of the Major Teaching Objectives of Science Education in the Secondary Schools of California.* Claremont: Claremont College, 1948 (Master's Thesis)

Ahrens studied shifts in objectives, showing scientific method ranking first in senior high school. He concluded that science teaching must relate more closely than in the past to the material and social aspects of life.

Alpern, Morris L. "The Ability to Test Hypotheses." *Science Education* 30:220–29. Oct., 1946.

Alpern devised and administered tests to high school pupils (a) to determine the degree of ability to select procedures to test scientific hypotheses and (b) to evaluate certain measurable factors related to this ability. Conclusions show that this ability to suggest procedures to test hypothesis depends in part upon the habit of delayed response, an element of the scientific method. Students with no training other than regular classroom instruction demonstrated the ability to suggest and select procedures to test scientific hypotheses. Girls did as well as boys in selecting procedures to test hypotheses. The strangest finding of the study was that the net relationships (as indicated by the coefficient of partial correlation) between the ability to select procedures to test hypotheses and chronological age, intelligence, reading grade and previous high school science experience, respectively, were not significant.

Collins, Charles W. "Correlations With a Conservation Unit." *The Science Teacher.* Vol. XV. No. 4, p. 165. Dec., 1948.

These authors show real skill in planning a functional unit getting other teachers interested in core curriculum. They evaluate by answering such questions as (1) Was the democratic process used in unit development or was it externally imposed? (2) Was there a continuous program of cooperative planning on the part of all faculty members who participated? (3) Did the unit grow out of the intimate interaction of teachers and students as they faced the social problem?

Diederich, G. W. "A Source Unit in Genetics." *Science in General Education.* D. Appleton-Century Co., 1938. pp. 524–579.

Example of source unit for use in high schools.

Fox, Adrian C. Conservation Series, Unit VII. *Soil Conservation in Public Schools. American Biology Teacher,* Vol. 10 No. 1, Jan. 1948. pp. 9–16.

Both the national need for conservation education and the needs of boys and girls to develop attitudes and habits about conservation, were considered. Questions such as, why the need to study this, can we do anything about it, etc., started the plan to put good teaching aids in the hands of teachers. Of course, this is not a pupil-teacher planned unit, but it might easily be. It certainly opens up one of our national problems which science education can help to solve.

Fulcher, Gordon S. *Better Thinking for Better Living.* Ann Arbor: Edwards Bros., Inc. 1948.

Although this is not set up for secondary schools it offers an excellent attack on straight thinking and problem solving. His analyses of errors in thinking and his concise outlines of steps are worth checking.

Gerard, R. W. "A Study of Educational Progress." *Higher Education.* Vol. XIX No. 1, January 1948.

Review of study on college which admits students at 11th and 13th year. Study begins in high school. Changes occurring tested. Method of establishing objectives in area of science and evaluation especially noteworthy.

Keeslar, Oreon. "A Survey of Research Studies Dealing with the Elements of Scientific Method as Objectives of Instruction in Science." *Science Education* 29:212–16, October, 1945.

Keesler made an analysis of literature dealing with the scientific method to derive a list of the elements of this method which would be suitable for instructional purposes in secondary schools. The list was checked for validation by twenty-two research scientists. Current opinion to the contrary, the investigator found that the elements of scientific method are definite, distinct from scientific attitudes, and known and used by scientists. The investigator believes that the use of his list of elements by high school teachers would improve the student's chances of success in meeting and solving everyday problems.

* By N. Eldred Bingham for the Committee on Research in Secondary School Science.

Oppe, Greta. "Atomic Education for Our Youth." Detroit: *Science Review.* February, 1948, pp. 16–17.

Example of resource unit for use in high schools.

Powers, Edward P. "A Unit in Aviation for Grade Six." *School Science and Mathematics.* Vol. XLVIII, No. 1, January, 1948, pp. 58–60.

Significant for method used in planning unit.

Subarsky, Z. "Human Relations in Our Time—A challenge to the Educator." *Science Education.* 32:138–42. April, 1948.

Subarsky, experimenting with a group which possessed little racial prejudice, found that by providing for two integrations of biology and social studies in a term, greater changes in racial attitudes were produced than by conventional courses.

Weisman, L. L. "Some Factors Related to the Ability to Interpret Data in Biological Science." Chicago: U. of Chicago, 1946. (Doctor's dissertation)

Weisman studied experimentally whether or not the ability to interpret data can be improved by an experimental method which she describes as one where the desired thinking outcomes are set up as definite aims of instruction. In an experiment carried on over 21 months, six biology classes were taught by the investigator using the experimental method, while six were taught by teachers considered equally good who thought that critical thinking would develop concomitantly as students followed the regular course of study. Miss Weisman concludes that the ability to interpret data can be improved in a tenth grade biology class by means of the procedures used in her study. There was a significant gain made by the experimental group in ability to interpret data. The success of the experimental method implied that to develop thinking objectives, the emphasis should be placed on the kind of thinking rather than upon memorization of facts and principles. This includes such behaviors as: recognition of assumptions, proper qualification of conclusion based on sampling, cautious use of predictions, and care in drawing reasonable conclusions and applying them to new situations. To realize the implications of this conclusion would necessitate a thorough reorganization of the science curriculum based on student interests and needs in the basic aspects of living and functioning in their community. It further implies a change in curriculum and method in teacher education.

Wise, Harold E. "The Measurement of Ability to Apply Principles of Physics in Practical Situations." *Science Education* 31:130–44. April, 1947.

Wise investigated to find the relationship between the abilities involved in conventional problem solving in high school physics and the ability to apply physical principles in out-of-school experiences. By means of elaborately designed and validated tests the investigator found that class problem-solving abilities are not identical with those involved in solving practical out-of-school problems. He found that the ability to recall principles of physics and the ability to make application of these principles are related to intelligence in approximately the same degree. Other findings were that the IQ is not a valid measure of the abilities just mentioned and that final grades in high school physics are not a valid measure of the ability to recall principles or make application of them.

TRENDS AND PROBLEMS IN GENERAL EDUCATION COLLEGE SCIENCE COURSES *

In summarizing material contributed by twenty-one leading colleges and universities to his recent monograph *Science in General Educaiton*,[1] Dean E. J. McGrath lists four possible objectives for non-science major students who take general education college science courses. These may be summarized as follows:

1. To understand and learn to use the method of science
2. To become acquainted with some of the more important facts of science
3. To become aware of the social implications of science
4. To appreciate the historical development of science.

Not all of these objectives may be realized or even expressed in any particular course, and certainly there are wide and almost

* W. C. Van Deventer, Chairman, for the Committee on Research in Junior-College Science, National Association for Research in Science Teaching.

[1] E. J. McGrath, Editor. *Science in General Education.* Dubuque, Iowa: Wm. C. Brown Company, 1948.

unmeasurable differences in the extent to which they are attained in the cases of individual students. They constitute, however, a composite general goal toward which general education college science teaching as a whole seeks resolutely to grow.

Among the teachers of general education college science courses there appears to be a trend toward a belief that all students (science majors as well as non-majors) can profitably take such courses. For non-majors they should constitute a general preparation for living in a science-dominated world. For majors they should furnish a basis for a broad integration of scientific knowledge. Because of these differing functions there is a feeling in some four-year institutions, as found in the N.A.R.S.T. committee's 1947 study, that separate integrating courses should be given, the one for non-majors being placed at or near the beginning of their college study, and the one for majors at or near the end of it. Even when only the early course is given, however, there is a wide and growing opinion that science major students can profit from it. Either there is no significant loss of time on their part, or such loss as may occur is more than counterbalanced by the values gained, and can easily be made up.

Another noticeable trend is toward a goal of "understanding science" rather than simply "knowing science," as was the case with many of the earlier courses. Although the phrase "understanding science" is borrowed from the title of the book by President Conant of Harvard on this subject,[2] it is not meant to imply that the approach which he suggests is the only approach to the problem of presenting such courses. There are several tried and proven ways of approaching the problem, and others are in process of experimentation in connection with various general education programs now in existence.

[2] Conant, James B. *On Understanding Science.* New Haven: Yale University Press, 1947.

As was pointed out in the committee's report of last year,[3] the better-established methods of organization and treatment fall into three general categories. These are (1) the subject matter or survey treatment, (2) the historical or cultural heritage treatment, and (3) the treatment based on problems or needs.

The subject matter or survey treatment is the oldest from the standpoint of general education science development. It is also the one (as indicated by the committee's work of last year, by Dean McGrath's monograph, and by Mr. Bullington's current study) which is still used in pure or modified form by more institutions than any other. Survey treatments may be integrated around subject-matter areas (the "traditional" survey course) or around subject-matter principles. In either case they attempt to "cover the ground." There is a trend, however, away from a total survey, which tends to be superficial but complete, toward a "block and gap organization," [4] which is thorough in the "blocks" that it covers, but is frankly incomplete. This method of organization depends on a connecting thread of method or philosophy, such as "scientific method and attitude," or an idea such as "man as a biological organism in relation to his environment," for achieving integration between the blocks.

The historical or cultural heritage treatment is based on the idea that the best way to understand science is to study its development. It is possible to combine the historical approach with the "block and gap" method. This involves dealing with selected historical situations thoroughly, factually and analytically. This is essentially the Conant case study technique. It is currently being tried experimentally in one course at Harvard. There has been

[3] "Report of Research Committee on Junior College Science." *Science Education.* Vol. 32, No. 3, April 1948.

[4] The writer is indebted to Dr. Eric M. Rogers, writing in the McGrath Monograph, for this term.

sufficient success that it is being continued and extended, with such modifications in detail as experience indicate are necessary.

It appears that there are three possible ways of utilizing the history of science in the teaching of general education science courses. These are: (1) using history as illustrative of accepted methods and principles of science, (2) using history as needed for understanding present day problems, and (3) using history as such, for developing an appreciation and understanding of the "atmosphere" of science.

In using problems as an approach to teaching an understanding of science there is a possibility of utilizing either historical and classical problems, or present-day problems and needs. The question involved in choosing between these alternatives is: Can a consideration of problems of the present serve as well as a study of historical problems in developing in the student an understanding of science?

Professor Alyea of Princeton, writing for the McGrath monograph, presents a convincing argument for the use of present-day problems, at least in conjunction with classical ones. He bases this on student interest in modern science developments and problems of the present-day world, as contrasted to the necessarily synthetic interest which may be engendered in historical problem situations. Stephens College uses present-day problems exclusively in its general course.

President Conant, however, in his book, *On Understanding Science*,[5] presents an argument in favor of classical problems based on the fact of their greater simplicity. They stem from a period in the early development of science, when the scientists themselves had little background for proceeding toward a solution of them. Therefore, the modern student with little scientific background is able to approach them in much the same way that the early scientists did. At the same time they constitute good examples of the way in which scientists of all periods have approached and sought solutions to problems.

The question of present-day problems versus classical problems for use in teaching involves the very real matter of building up interest, and even of overcoming antagonism in the minds of non-science major students. This is a very real classroom problem, and upon its solution depends in large measure the success or failure of the whole program of presenting science to non-science students in such a way that they can derive lasting value from it. In the last analysis, however, the development of student interest probably depends less on the method used than upon the personality of the teacher who is using it, and the kind of students or local situation with which it is used.

Paralleling any attempt to utilize present-day problems in teaching general education science courses is the question of needs. What do students need? How are we going to find out what they need? Are we going to concern ourselves with their present needs or their probable future needs, or both? When we think of needs do we mean individual needs or social needs, or both? To what extent is there a community of needs within a group? What attention should we pay to the "fringe" of individual needs which do not fit into the "common core" of group needs? How often should needs be restudied? There is no total answer which appears to this imposing list of problems. All general education science courses at the college level attempt directly or indirectly to deal with what their planners believe to be student needs. Two of the courses described in the McGrath monograph mention studies of student needs as a basis for course organization. These are the course at the University of Louisville and the one at Stephens College. Little uniformity of treatment, however, is ap-

[5] Conant, *op. cit.*

parent in the descriptions of these two courses.

The social aspects of science and the impact of science on society also constitute a kind of problem-area from which it is possible to draw material and inspiration leading toward an understanding of science by the general student. This is widely recognized by curriculum-planners and teachers. Of course thinking concerning the social functions and responsibilities of science received considerable impetus as a result of the war. Teaching in this area constitutes the most frequent modification of courses in the direction of the problem approach. In general, it belongs with the use of problems of "here and now" rather than with historical problems, although it has important historical roots.

A third trend in the development of general education college science courses has to do with the use of the laboratory. In the traditional "cook-book" type of laboratory, characteristic of many first-level college science courses, the student is given material, directions and supervision, and works for correct answers. This simply illustrates principles laid down in lectures and textbooks. The general failure of this type of laboratory in general education science courses has been due to: (1) Lack of time, (2) Size of classes, (3) Lack of adequate equipment, and (4) Inability to solve the problem of "what to leave out."

One possible solution to the laboratory question has been the substitution of demonstrations, partly or wholly, for laboratory work. This has been done, of course, for a long time with varying degrees of success. In some institutions it is done quite frankly and effectively, and has been given good support by both faculty and student evaluation. In many other schools demonstration work has definitely been used as an expedient, with a wish for something better. Demonstration work alone is probably not the complete answer to the laboratory problem, although there appears to be a growing feeling that most, or possibly all, lectures should be illustrated with demonstrations or some type of visual materials. The increased use of such audio-visual aids as sound motion pictures and recordings has helped to meet the need for adequate demonstrations.

A new type of laboratory is being developed in some courses as a substitute for the traditional "illustrative" laboratory. This is "finding" or exploratory type of laboratory. In it students work on only a few problems. They are furnished with equipment, materials, sources of information and general directions, but they are required to work out the problems "on their own," and not toward cut-and-dried answers. This type of laboratory is used both with classical problems from the history of science, and modern problems "of life and living." It is also used to some extent in more or less traditional courses, where major emphasis is placed on learning scientific method.

As is the case with any new departure, the methods of application of the "finding" type of laboratory vary widely. There are almost as many variations of it as there are schools using it. Of the courses described in the McGrath monograph, Princeton uses it with a mixture of classical and modern problems in a single-science type of general course designed for non-majors. Western Washington College of Education uses a combination of demonstration techniques and a "finding" type laboratory, based on modern problem materials, or on orthodox laboratory materials oriented in terms of modern problems and interests. Kansas State Teachers' College uses a modified "finding" type laboratory with rather careful supervision, to accompany a survey approach. Antioch College uses various "finding" or exploratory techniques in connection with a well-integrated survey-problems-historical course organization.

It seems that what may be needed is a broader concept of the meaning of laboratory work. We have been bound to the idea that it must necessarily consist of

something manual, and something which is confined within the four walls of a room called a laboratory. Actually a laboratory *experience* (as contrasted to a laboratory *experiment*) may consist of any problem-solving situation, provided the problem is a real or recognized one for the person having the experience Under this concept, laboratory experiences and materials may include anything used or useful in finding solutions to problems. This includes not only traditional laboratory materials and experiences (as well as experiments), but also such experiences as seeing motion pictures, hearing recordings, making surveys, taking field trips, engaging in discussions, and even listening to lectures, provided these contribute to the solution of real or recognized problems.

This concept of the laboratory is applied in the General Biology course at Stephens College.[6] It necessarily implies a certain amount of attention to the specific needs of individuals and individualized instruction, but it does not in any way preclude carefully planned and motivated group experiences of all commonly-used types. Traditional types of laboratory experiments find a place in it, either as small group demonstrations in which students actively participate or as individual experiences.

A fourth trend in connection with college science courses of the type that we are considering has to do with teaching materials. The important and increasing use of audio-visual aids has already been mentioned. There appears also to be a tendency on the part of many teachers of such courses to utilize a number of texts in the library rather than a single text that the student owns. Sometimes "clubs" of two or more students are asked jointly to purchase two or more textbooks, each especially appropriate for certain parts of the course, and serving to supplement one another. To some extent these groupings constitute devices for getting around a lack of adequate single texts. In other cases, however, there is a definite feeling on the part of teachers that students should not be allowed to form the habit of looking to a single text as authoritative.

When the library is thus extensively and intimately used for a teaching as well as a reference tool, it becomes necessary to give careful attention to the development of a particular type of library designed for this kind of use. One of the schools contributing to the McGrath monograph, Boston University, makes special mention of building up a type of library designed for general education teaching. This parallels the experience at Stephens College where a special department of the library has been created for this purpose.[7]

Along with greater use of library references rather than textbooks in the limited sense, there is a notable tendency in connection with many of these courses for teachers to write their own supplementary materials, and publish them for student use in mimeographed form. This is in part a further response to the lack of suitable textual publications. It is also in part due to the realization that courses of the type with which we are dealing must necessarily be tailored to fit local institutional needs, and the needs of specific groups of students. Frequently they are tied to the local environment through extensive use of community resources. No text can ever completely fit them unless it is written specifically for them. This tendency is at once the joy and the despair of textbook publishing companies. On the one hand it furnishes them with an inexhaustible mine of possibilities in the form of new writers and ideas. On the other hand it necessarily makes for a lack of uniformity which renders the textbook writer's and publisher's job more than normally difficult.

[6] Van Deventer, W. C. *Individualized Instruction in a Basic Science Course. Science Education.* Vol. 30, No. 5, December 1946.

[7] Johnson, B. L. and Lindstrom, Eloise, Editors. *The Librarian and the Teacher in General Education.* Chicago: American Library Association, 1948.

Up to this point we have considered only those mimeographed materials which consist of original syntheses prepared by the teachers themselves. Those who are experimenting with courses following the historical approach or utilizing historical materials in connection with other approaches have frequently found it necessary to reproduce in mimeographed or reprinted form some of the original papers which they utilize in connection with their presentation. The University of Chicago and various others have made use of this technique.

Some of the major problems in connection with the organization of general education college science courses have been administrative. One of these involves the danger of the loss of the individual in the mass. From the beginning these courses have been designed for the large number of non-science majors rather than for the smaller number of potential science specialists. Now with our vast increases in enrollment and consequently inadequate facilities, it has become even easier than before to lose sight of the individual and his needs. One member of the committee especially has felt that this should be given prominent mention.

This problem is further pointed up in junior colleges by the necessity of setting mass standards for those students who are planning to transfer to four-year institutions. Under the system by which this transfer most commonly takes place the emphasis is on grades. Grades, in turn, are most easily defined in terms of the ability of the student to reproduce learned facts on demand. This leads to an emphasis on subject matter which may well be dangerous from the standpoint of meeting the needs of individuals for "understanding science." Is subject matter primarily what our general education students need? Or should subject matter constitute a tool to use in teaching attitudes and understandings?

This danger becomes particularly apparent in connection with our methods of evaluation. There is a need for tests or other methods of evaluation which will locate ideas, attitudes and understandings, without at the same time emphasizing the subject matter in terms of which these are taught. Much work and thinking has been done in this area, but we certainly do not as yet have a complete answer to the problem. The University of Chicago has probably proceeded farther and more thoughtfully along this line than any other of the institutions that have come under our committee's observation.

A second administrative problem has to do with teaching personnel. In the opinion of one member of the committee the lack of adequately trained teachers in this field constitutes the weakest part of our general education science program. Connected with this is the problem of teachers feeling inadequate when working in broadened courses which reach outside their fields of specialty. In some institutions this has been met partly by in-service training of teachers, working in cooperation with colleagues trained in other fields. Teachers in courses of this type frequently find that their job takes on new aspects. In the account of the course at Colgate University, in the McGrath monograph, this new type of teacher is described as "moderator, guide and listener." As the student and his need for acquiring an understanding of science in relation to his life are brought into the course, the new functions of the teacher become defined. These demand a new type of educational training, either preservice or in-service, for such teachers.

Another faculty problem is that of inadequate advancement and prestige for those engaging in general education teaching. Many institutions in describing their general courses make mention of the fact that doing an adequate job of this type of teaching precludes or limits possibilities of subject-matter research. Yet teachers, especially in large universities, who work in such courses must necessarily compete

for advancement with those who are attempting to climb the advancement ladder in the more traditional and accepted fashion, by carrying on subject-matter research in their special fields. There is a great need for recognition on the part of both administrators and colleagues, that good teaching is equivalent in value to good researching. In some cases well-integrated general education science courses, with several years' experience behind them, have been abandoned in favor of a return to more traditional curricular procedures, because of the antagonism of fellow faculty members or lack of cooperation on the part of administrators.

There are also purely mechanical problems having to do with such questions as whether the course shall be taught by one instructor who integrates materials from all subject-matter fields, or by an interdepartmental staff of subject-matter specialists; and whether the course shall contain both physical and biological elements or divide these into separate courses. For these questions there are apparently no perfect answers. Notably successful uses have been made of each method in different institutions. Of the courses described in the McGrath monograph, Colgate University and Stephens College use a single teacher for each group of students. Haverford College and Northwestern University are examples of institutions utilizing several teachers from different subject matter fields. Northwestern, Boston University and Stephens integrate physical and biological materials into a single course. The University of Kansas City, Colorado State College of Education, Colgate, University of Iowa, University of Wisconsin and many others separate them. It is possible to make a good case for any of the accepted procedures. Apparently the success of a course depends on other factors than these matters of course mechanics.

It seems possible by way of summary to consider the applicability of a kind of "comparative anatomy" of general education college science courses. We have mentioned three major elements, approaches or methods of treatment in the organization of these courses. These are the "survey" or subject-matter element, the "historical" or cultural heritage element, and the "problems" or needs element. One or more of these is found in the description of any general education college science course. Most frequently all three of them, with varying degrees of emphasis, are found in a particular course.

Some courses balance the three elements about equally, as in the one at Antioch College. Others are mainly historical as at Wesleyan University. Still others emphasize problems as at Stephens College. Major emphasis on the "subject-matter" element is to be found in the "survey courses" which are given in many institutions. These may be integrated either on the basis of subject-matter areas or subject-matter principles. In utilizing any of these three elements or approaches a course may be so organized that it attempts complete coverage of the field, with consequent sketchiness of treatment, or it may be frankly "block and gap," sacrificing completeness for depth.

This three-way characterization is equally well applicable to single science courses and to those utilizing material from several sciences. When this is used in conjunction with a few other considerations it is possible to arrive at a simplified picture for comparative purposes of any of the general education college science courses so far described. The most important of the other considerations are: How the course meets the question of laboratory, how it adjusts to the necessity of dealing with the individual in the mass, whether it uses one teacher for all phases of the course or a committee of subject-matter specialists, whether it deals with only a single science or integrates materials from several sciences, whether or not it includes both physical and biological materials, and how it evaluates its products.

New techniques and new approaches to the problem of organization are being suggested and tried out. One interesting possibility, which might well constitute a fourth organizational element along with the "survey" "historical" and "problems" approaches which we already have, is that of orientation of general education in science around the "problem of meaning." If this involves some consideration of science and religion, along with other aspects of science in relation to man's thinking and the kind of world that man has built for himself, perhaps it is time that we faced this frankly.

Professor Kimble of Harvard has given some attention to this phase of science education in his physical science course. McGrath mentions that there are a few others who are doing so, but does not cite them. In some sections of the General Biology course at Stephens College experiments dealing with the presentation of science in relation to the problem of meanings have been in progress for three years. These have led to very satisfactory results. It seems probable that the meaning of science may furnish as good an approach to the goal of "understanding science" as do the subject-matter of science, the historical development of science and the service function of science in relation to human needs.

PROGRESS REPORT OF THE COMMITTEE ON RESEARCH IN SECONDARY-SCHOOL SCIENCE *

DURING the past year the Committee on Research in Secondary-School Science has continued its work in accordance with plans of action reported at the annual meeting of NARST last year. Although the primary concern of the committee is to promote research upon the objective of science teaching commonly referred to as problem-solving, it has also been concerned with what science teachers are doing about problem-solving in their teaching.

As was reported last year, some members of the committee considered it desirable to prepare a statement of the committee's point of view regarding the general nature of problem-solving and its significance in science teaching. Even though a number of investigations of the nature of problem-solving have been conducted and reports of local and national committees have defined problem-solving in terms of classroom procedures, the term "problem-solving" when used in referring to an objective of science teaching does not mean the same thing to all science teachers. For this reason, a statement from this committee was considered desirable, by a number of the members, in order that those co-operating with the committee in its work might have a better understanding of what the committee means by problem-solving. It should be pointed out here that not all members, attending the last committee meeting, have considered such a preliminary statement desirable at this time. Because of the diversity of points of view regarding problem-solving, they consider a preliminary statement to be premature. Others felt that because of this condition, it was especially important that a preliminary statement be prepared and submitted to the membership of NARST for criticism. Based upon points that were brought out in discussion, at our last committee meeting, of a statement that had been prepared earlier, a preliminary statement generally acceptable to the majority of

* Summary of reports given by N. Eldred Bingham, W. Edgar Martin, and J. Darrell Barnard for the Committee on Research in Secondary-School Science, National Association for Research in Science Teaching.

the committee has been prepared by Dr. Elsa Meder. The preliminary statement appears in this issue of *Science Education*. The committee invites you to read it and criticize any part with which you do not agree.

Dr. W. Edgar Martin, a member of the committee, has carried forward with the task of obtaining a list of specific problems, dealing with the teaching of problem-solving, which members of NARST and other science educators consider important to investigate. A questionnaire designed to obtain the specific problems was designed by Dr. Martin and sent to 160 members of NARST and other individuals who were considered qualified to participate in the survey. Fifty replies have been received to date and a preliminary tabulation of data from these replies has been made.

The tabulation of the specific replies to the questions proved to be particularly difficult because of the varied opinions and convictions held by the members of NARST in relation to the characteristics of the various phases of problem-solving. In many cases it was difficult to assign the replies to a specific category or classification without reference to the point of view (philosophy) of the person responding. For example, phrases describing generally accepted steps in problem solving, such as: defining and delimiting the problem, setting up tentative hypotheses, evaluating data, and reaching a valid conclusion, seem to be fundamentally different procedures when they are analyzed in terms of the point of view of the respondent as to the nature of problems, how they arise, and how they can be defined and attacked in the classroom.

The fifty people, who have so far returned their questionnaires, suggested 193 different kinds of problems as being in need of investigation. The meanings stated or implied by these 193 different kinds of problems are additional evidence that there is a diversity of opinion regarding problem-solving among people who are active in the field of science teaching and who, presumably, are using the techniques frequently.

Based upon the analysis which he had made of the fifty questionnaires, Dr. Martin reported that there are controversial points of view among these science educators in regard to the origin of problems; the kinds of problems which are suitable for secondary pupils; the essential steps and techniques in problem solving; the different skills and abilities which are essential for successful problem solving; the evaluative instruments and techniques to be employed for introducing problem solving into more secondary-school teaching situations. In terms of these preliminary returns, it would seem that this committee has identified an area of science teaching in which a great deal of study is needed.

Steps are being taken to obtain all questionnaires by April 1 from those who have not yet returned them. The analysis of all returns will then be completed and an attempt will be made to prepare a meaningful and functional organization of the specific problems, related to the teaching of problem-solving, which need to be investigated.

Another project of this committee has been to explore what state science teachers' associations are doing toward the promotion of interest in problem-solving as an outcome of science education. This project was carried on during the year under the supervision of Miss Edith M. Selberg. Letters were sent to a representative of each of the state science teachers' associations to determine what his association was doing for its membership to promote interest in problem-solving. None reported that his association was doing anything with problem-solving. Several reported the names of teachers in their associations who were attempting to do something with problem-solving in their classes. Reports have been obtained from a few of these teachers regarding the nature of their work. From the evidence obtained, it would seem reasonable to generalize that little if anything is being done by state science teachers' as-

sociations to promote interest in problem-solving or to help science teachers do anything about it in their classes.

An attempt to locate promising practices in teaching problem-solving and to bring these to the attention of the membership of NARST was carried on during the year under the supervision of Dr. N. Eldred Bingham. Dr. Bingham and certain members of the committee prepared a bibliography of references in which promising practices in problem-solving were described. The bibliography was distributed to members attending the February meeting in New York.

Dr. Bingham also described a co-operative research project, involving science teachers in various sections of the country, which is being conducted under his supervision. The project illustrated an effective program for carrying on needed research and at the same time encouraging the teaching of problem-solving in more science classes. The research project is entitled, "A Direct Approach to the Teaching of the Scientific Method." Ten different "instruments" have been prepared or are in the process of being prepared for each of four science courses, general science, biology, chemistry, and physics. Each instrument consists of: (1) a problem to be solved, such as, How does water affect a hot fat fire?; (2) directions, for cooperating teachers, regarding the types of activities to be carried on with control and experimental groups; and (3) a test including elements of the scientific method. Although the research project has not been completed the preliminary findings, which are reported by Dr. N. Eldred Bingham in this issue of *Science Education*, indicate that the final results will add greatly to our understanding of the effectiveness of a direct approach to teaching the scientific method.

During the coming year the committee hopes to complete its work toward identifying the specific problems in the area of problem-solving which need to be investigated. It also intends to continue its search for promising practices in the teaching of problem-solving.

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PROBLEM-SOLVING AS AN OBJECTIVE OF SCIENCE TEACHING *

WHEN the Committee on Research in Secondary-School Science was appointed in February, 1947, it was charged with identifying an area or areas in which research was needed and with attempting to foster such research. The Committee has agreed to focus its attention on the broad area of the development of problem-solving as one in which research is needed. Now it is seeking means to promote research leading to an understanding of how problem-solving ability is developed. It regards its effort as justified because, although much has been said by science educators regarding the desirability of the objective of de-

* Statement edited by Elsa Marie Meder for the Committee on Research in Secondary School Science.

veloping problem-solving behavior, there is little evidence that present programs of instruction are attaining that objective.

The Committee recognizes that problem-solving ability is not developed at the secondary-school level alone, nor only in science classes, nor solely by the use of science materials. But it accepts as a basic premise the idea that the work of secondary-school science classes can contribute to the development of the problem-solving abilities of the young people in those classes. The task is to identify and describe ways in which such a contribution can be made, not alone in theory but in actual classroom practice. To this end, the Committee hopes to enlist the cooperation of many teachers throughout the country. That these teachers and the Committee members may have a common conception of the term *problem-solving,* the preliminary statement here presented has been prepared.

The Committee recognizes that any statement of problem-solving involves taking positions on controversial issues. Important philosophical ideas underlie any such formulation.

PROBLEM-SOLVING BEHAVIORS

Problem-solving may be considered a general type of human behavior. When a person exhibits this type of behavior, he is often enabled to resolve perplexing situations and to make satisfactory adjustments to various aspects of his environment. Problem-solving involves certain specific, interrelated behaviors, which may be summarized quite simply.

First, there are those behaviors which are concerned with the identification of problems. In this regard, an individual who exhibits problem-solving behavior recognizes situations involving problems which need to be solved. He identifies a definite problem within a recognized problematic situation, and determines whether or not that problem is susceptible to solution by empirical techniques. If it is, he states it in clear, concise, and unambiguous language, and proceeds to analyze it into its essential parts.

The finding of problems is essentially creative, not routine. It involves choices which are personal. Which of the infinite number of possible relations among ideas constitute problems? Which problems might be attacked successfully? Which problems if solved would be important in themselves, or in leading to other problems worth attacking?

A second group of behaviors relates to the establishment of the facts about the problem. The persons engaged in problem-solving recalls experiments related to the problem, and makes new direct observations as carefully and as frequently as possible. He obtains other pertinent information from reliable sources. He checks his facts one against the other.

Then there are behaviors related to the formulation of hypotheses. The person showing problem-solving behavior uses the facts he has checked as his premises for the formulation of hypotheses, or possible solutions to the problem. He recognizes, however, that his hypotheses are necessarily based not only on facts but also on assumptions, and he is well aware what assumptions have been made and what their limitations are.

Next are behaviors related to the testing of hypotheses. These include the solution of the most reasonable hypothesis from among those formulated; that is, the one most closely related to the facts and most readily subjected to verification. They include also the devising of means for verification and, necessarily, they include the testing itself, with as much precision and as frequent repetition as needful and in as many different ways as possible.

Finally, there are behaviors concerned with the results of the tests. The tests may show the correctness of a certain hypothesis; the new fact that is thus found may serve to direct action, to change ideas or viewpoints, to initiate further investigation. They may show only negative results, but

these, too, may direct action, change ideas, and stimulate study. Most often, perhaps, tests of hypotheses lead to tentative conclusions and resultant inferences, on which the individual concerned is bound to act. While acting on these conclusions, he is aware that new facts may come to light which will require reconsideration of his problem; that his actions themselves change the situation that called them forth; that the conclusion at which he arrived is not necessarily or even probably the final solution to the problem.

VARIATION IN THE PATTERN OF ACTIVITIES

Problem-solving behavior does not *require* a strict sequence of activities. Usually, to be sure, it is initiated upon recognition of a definite problem; usually, too, it progresses in a somewhat regular sequence. But there may be false starts or irregular progress. An individual may believe that he has identified a definite problem and set about to solve it. As he proceeds with the solution, he may discover that the problem he is attempting to solve is not the really significant problem. He may then identify what appears to be the more significant problem and reorganize his procedure toward its solution. Similarly, hypotheses may be formulated on the basis of comparatively few facts and revised as more data are collected, or they may be formulated only after a great deal of information has been accumulated.

ABILITIES AND ATTITUDES BASIC TO PROBLEM-SOLVING

The extent to which an individual exhibits specific problem-solving behaviors is determined in part by the abilities he possesses. For example, a basic skill is the ability to read with understanding; another is the ability to communicate effectively with other persons. Still others are skills in observation, in selecting pertinent data, in recognizing what facts are irrelevant to a problem, in recording data, and in organizing data so that facts may be compared, checked, and related to each other.

Also basic to problem-solving behaviors are certain attitudes. One of these clearly is curiosity. Another is a predisposition to weigh evidence and to suspend judgment until adequate consideration has been given to the evidence and to the alternatives. An attitude of openmindedness, of freedom from preconceived ideas, is fundamental. So is willingness to be convinced by evidence. And so also is courage to make a choice and to act on a decision.

SITUATIONS EVOKING PROBLEM-SOLVING

Human beings try to understand the world in which they live—both the world of natural events and the world of social events; they try to understand themselves and their fellows; they seek peace and security, freedom and justice, and beauty. Their strivings lead to problems of diverse nature and varying complexity.

At least some of these problems are susceptible to solution by individuals exhibiting the problem-solving behaviors described. Among them are, of course, those which have ordinarily been accepted as lying entirely within the subject-matter limitations of the natural and physical sciences, such as: What happens when water boils? How do plants respond to light? Why does the wind blow? However, problems involving social and economic relations may also be attacked by similar means —problems such as: How can the health of our community be improved? How can our natural resources be used more wisely? How can prejudice against minority groups be lessened? It may be that more exact and refined techniques are available for solving the "purely scientific" problems than for attacking the "socio-economic" problems, but it is in the solution of problems of the latter sort that general problem-solving behavior becomes of immediate social signifiicance.

Both "scientific" and "socio-economic"

problems vary in degrees of complexity. The same general problem-solving behaviors are used in solving simple problems and in solving more complex ones. Here, for example, are three problems of varying complexity, each clearly requiring similar behaviors on the part of those attacking them:

How are white rats affected by a diet deficient in Vitamin A?
What nutrients may be found in orange juice?
How may the Vitamin A content of the average American diet be raised to optimum levels?

Problem-solving in the classroom

Problem-solving, like other forms of activity, can be both an individual and a group process. Probably each person needs experience of both kinds: working as an individual with sole responsibility for the outcome, and working as a group member with shared responsibilities.

Sometimes a student will work on his individual problem—perhaps the same problem other class members are studying, perhaps one that is uniquely his. At other times he will work with a small group; on still other occasions, an entire class will cooperate in solving a problem. A combination of individual and group work may be used: the class as a whole may identify a major problem, analyze it into more specific subproblems, and assign the subproblems to individuals or small groups for solution.

Problem-solving can be carried on at the various maturity and intellectual levels represented in our schools. There may, to be sure, be differences in the types of problems solved at various levels. Where an elementary-school class might consider the problem, "What kinds of materials do magnets attract?" a secondary-school class might study the problem, "How does an electric motor work?" There are differences also in the depth to which the solution of a problem is pushed. For example, a high-school biology class and a college class in plant physiology may both be concerned about the same problem, namely, "How do plants respond to light?" The high-school class may be satisfied with finding out about the more obvious responses of plants to light and darkness; the college class may investigate many of the less apparent effects of varying light intensities upon photosynthesis, transpiration, and blooming.

It cannot be taken for granted that problem-solving is a pervasive activity in classrooms or even an occasional one; nor is it safe to assume that problem-solving occurs automatically in science classes because of the nature of the subject matter. Much effort is required and much work remains to be done if problem-solving is to become an integral part of the educational process.

REPORT OF THE COMMITTEE ON ANNUAL MEETINGS

Recommendations

1. That the National Association for Research in Science Teaching (NARST) continue the practice of holding an annual national meeting each year.
   a. That this meeting be held in conjunction with that of the American Association of School Administrators (AASA), in years when this organization holds a single national meeting.
   b. That the national meeting of NARST be held in conjunction with the national meeting of the Association for Supervision and Curriculum Development (ASCD) or with one of the regional meetings of AASA, in years when the AASA

does not hold a single national meeting.

c. That the Executive Committee of NARST should give consideration to the holding of their national meeting in conjunction with a meeting in the middle west (either ASCD or a regional meeting of AASA or some other organization), in years when AASA does not hold a national meeting.

2. That, in addition to the annual national meeting of NARST, the following machinery be set up for developing and promoting regional meetings of NARST each year.

a. A standing committee on regional meetings should be appointed, with a budget of $100 annually, for organization and promotion of regional meetings.

b. This committee would be charged with finding out those members of NARST who are actively affiliated with other organizations with which members of NARST might profitably hold regional meetings.

c. This committee would appoint regional chairmen who were so affiliated and strategically located, and charge them with arranging regional meetings as desired, in conjunction with appropriate educational organizations. (* See appended suggested list.)

d. This committee would distribute money from its budget to regional chairmen, as needed to defray expenses of correspondence, printing of programs for regional meetings, etc., but not personal expenses of attendance.

3. The programs of regional meetings of NARST would consist of

a. Research papers contributed by persons within the area served by the meeting.

b. Discussions of NARST business, either

(1) Affecting the regional group only, or

(2) Initiated by the regional group and referred by it to the national meeting for final decision.

c. It would be the responsibility of the regional chairmen to select from these research papers those of apparent national significance, and either

(1) Present digests of them at the national meeting, or

(2) Encourage persons presenting the papers to present digests of them at the national meeting, subject to the approval of the Executive Committee acting in its capacity of a program committee.

4. The programs of national meetings of NARST would consist of

a. Reports of research committees such as those now in existence.

b. Consideration of business affecting the organization as a whole.

c. Digests by regional chairmen of outstanding research papers presented at regional meetings, or in occasional cases, presentation of digests or summaries of these papers by the authors where this was desirable and possible.

d. Presentation of research papers by persons from the immediate area served by the national meeting, or elsewhere. (The setting up of regional meetings should in no way prevent individuals from other areas than that served by the national meeting from bringing papers to it directly, instead of reporting them at a regional meeting.)

5. The national meeting of NARST would be held in late winter or early

spring, and would include insofar as necessary a summary of all regional meetings of NARST that had been held during the preceding summer, fall and winter.

6. The April issue of *Science Education* would carry the material presented at the national meeting, and would therefore make such material available to members unable to attend.
7. Papers presented at regional meetings of NARST would be eligible for consideration for publication in other issues of *Science Education*, but such publication would not be obligatory.

The committee feels that institution of this program would help to fulfil the following functions:

1. It would provide opportunity for nearly all members of NARST to participate in either a regional or the national meeting of the association each year.
2. It would widen the avenues for presentation through NARST of valuable research studies in science education.
3. By carrying the activities of the organization into all sections of the country, it would increase the prestige of the organization and its membership, and would thereby contribute to a solution of the problem of securing for people working in science education adequate recognition by faculty colleagues and college administrators.
4. By utilizing as regional chairmen those of the membership who are already active in other educational organizations, it would accomplish these aims with a minimum of expenditure and organizational difficulty.

Respectfully submitted,

ELSA MEDER
PHILIP G. JOHNSON
W. C. VAN DEVENTER, *Chairman*

Suggested List of Educational Organizations with which Regional Meetings Might Be Desirable

1. Regional meetings of the American Association of School Administrators, in years when these are held.
2. Association for Supervision and Curriculum Development, if this was not in conjunction with the national meeting of NARST.
3. Central Association of Science and Mathematics Teachers.
4. American Association for the Advancement of Science (Section Q).
5. Conference on Teacher Education in Science.
6. A far western group, possibly the western summer meeting of AAAS.
7. Texas Education Association, or other similar state groups.
8. National Association of Secondary School Principals.
9. American Educational Research Association.
10. National Association of Biology Teachers.
11. New England Association of Chemistry Teachers.
12. American Association of Physics Teachers.
13. National Society for the Promotion of Engineering Education.
14. American Chemical Society.
15. American Physical Society
16. Geological Society of America.

(The last three customarily meet separately from the AAAS.)

This list could be expanded almost indefinitely. It is not contemplated by the committee that regional groups would meet

with all of these societies, but only that meetings be arranged with such of them as seemed desirable and profitable to the Regional Meetings Committee, and to interested members of NARST. It is further recommended by the committee that not more than four such regional meetings be attempted the first year, or possibly in any year, but that these be well distributed in different areas of the United States in order to give as great a geographical coverage as possible.

A DETERMINATION OF PRINCIPLES AND EXPERIMENTS FOR AN INTEGRATED COURSE OF PHYSICAL SCIENCE FOR HIGH SCHOOL—II *

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STATEMENT OF THE PROBLEM

THE PURPOSE of the second part of the investigation [1] was to determine the relative values of the experiments which are desirable for inclusion in an integrated course of physical science for senior high school, and whether each of those experiments would more appropriately be done as a laboratory experiment or as a demonstration.

DEFINITIONS OF TERMS

The following definitions of terms not previously defined were used in this part of the investigation:

The term "experiment" means any kind of activity in connection with which apparatus or materials are manipulated or field trips are made in an attempt to solve a problem in the field of science.

A "laboratory experiment" is one which is pupil-performed for observation by only the performer or performers.

A "demonstration experiment" is one which is performed by the teacher and/or one or more pupils, and is for observation by all members of the class.

TECHNIQUES EMPLOYED

The solution of the main problem of the second part of the investigation involved, first, the completion of two minor problems, namely:

1. To assemble experiments appropriate for use at the senior-high-school level.
2. To assign these experiments to the various principles of physical science.

Method of Assembling Experiments

Textbooks and laboratory manuals, along with masters' theses and doctors' dissertations, were considered to be appropriate sources of experiments.

A list of 30 publishing houses, which were deemed by the investigator as most likely to publish textbooks and laboratory manuals of science for use in senior high schools, was selected from *The Publisher's Trade List Annual, 1945* [2]. Two sales representatives of large publishing houses were asked to add to the list the names of other houses which publish textbooks or laboratory manuals of science for use in senior high schools. They added no publishers to the list.

The latest catalogues, in which books of high-school science were listed, were se-

* This article is based on one section of the author's dissertation for the degree of Doctor of Philosophy, University of Michigan, 1947. This article is a continuation of a report of the investigation of which Part I appeared in the March 1949 issue of SCIENCE EDUCATION. Paper presented at New York City meeting of The National Association for Research in Science Teaching, February 15, 1949.

cured from these publishers. A list of all textbooks and laboratory manuals of physical science for use in high schools was compiled from these catalogues. The latest editions or revisions of these books were then ordered from the companies. Forty-five textbooks and 44 laboratory manuals were received.

The textbooks and laboratory manuals were examined by the investigator, and those which satisfied the following four criteria were retained for further consideration as possible sources to be analyzed for experiments:

1. The publication must be intended for use in the senior high school as stated in the preface of the publication, or in the publisher's catalogue.
2. The publication must be intended for use as a textbook or a laboratory manual in one or more courses of physical science offered in senior high schools and commonly called physics; chemistry; physical science; earth science, physiography, or physical geography; consumer science; senior science; or aeronautics.
3. The publication must be the latest edition or revision available from the publisher in November, 1945.
4. The publication must have a copyright date during the decade 1936–1945, or have had at least 5 reprintings during that decade.

Forty-three textbooks and 43 laboratory manuals satisfied the four criteria. From these textbooks and manuals, the following groups were chosen for analysis as sources of experiments:

1. The 5 textbooks of physics and the 5 of chemistry, selected after a page-by-page analysis of all 29 such books, as the ones which would provide a greater number of different experiments than would any other similar number.
2. All 14 textbooks of the physical sciences, in addition to those intended for use in separate courses of physics and chemistry.
3. All 43 laboratory manuals, including from 1 to 20 for each of the physical sciences.

The numbers of textbooks chosen for analysis as sources of experiments were, according to subject-matter fields: physics, 5; chemistry, 5; aeronautics, 4; consumer science, 2; earth science, 4; physical science, 4. The numbers of laboratory manuals were: physics, 20; chemistry, 17; aeronautics, 1; consumer science, 1; earth science, 3; physical science, 1.

The following reference sources were searched for possible sources of lists of physical-science experiments, exclusive of textbooks and laboratory manuals:

Bibliography of Research Studies in Education, 1926–1939, inclusive.
Doctoral Dissertations Accepted by American Universities, 1933–1945, inclusive.
The Education Index, 1929–1945, inclusive.
Readers' Guide to Periodical Literature, 1900–1945, inclusive.
Education Abstracts, 1936–1943, including the continuation of such service in *The Phi Delta Kappan*.
Cumulative Book Index, 1928–1945, inclusive, including the United States Catalogue of books in print January 1, 1928.

Six sources of experiments were secured as a result of the searching of the reference sources.

From all these possible sources of experiments the final selections included 73, namely, 24 textbooks, 1 non-textbook, 43 laboratory manuals, 3 masters' theses, and 2 doctors' dissertations. All statements of the purposes of experiments, which were followed by directions for their performance, were collected from these sources. Each of the 73 sources was read page by page, and the purpose of each experiment so located was written as a question on a separate three-by-five white card. The source of the experiment was also designated on the card by author, title, and page.

In all, approximately twenty-three hundred experiments were secured from these sources. As a means of detecting and eliminating duplications, the experiments were assigned to different categories. Those for physics were: mechanics, heat, sound, light, electricity, modern physics, astronomy, and meteorology. Those for chemistry included acids, bases, salts, oxygen, hydrogen, nitrogen, sulfur, and metals. All experiments in geology were grouped together and not assigned to categories.

When the duplicate experiments had been eliminated, it was found that closely related experiments could be combined by

restating the purpose. For example, the following multiple purpose represents a consolidation of five experiments previously carded separately from different sources:

> Can heat energy be produced by compression (using a bicycle pump)? By friction (rubbing hands)? By electricity (connecting two terminals of a dry cell with a small copper wire)? By a chemical change (pouring sulfuric acid on sugar)? By light (passing light through glass to a piece of metal painted black)?

As a means of facilitating the subsequent assignment of experiments to principles, every experiment which was found only in a physics source was written on a yellow card; every one found only in a chemistry source was written on a salmon card. All other experiments were written on blue cards.

Reliability

A possible source of variability, inherent in the technique employed, existed in the selection of experiments from textbooks. It was reasonable to assume that there was negligible, or no, variability in the selection of experiments from the laboratory manuals, theses, and dissertations, because the experiments in them were clearly indicated. The experiments in the textbooks, however, were not so clearly indicated. Only those in the textbooks, therefore, were used in computing an "index of reliability" of the analysis to secure the experiments.

One-hundred pages selected at random from 2 textbooks, 1 of physics and 1 of chemistry, were re-analyzed 6 months after the first analysis of them. It seems reasonable to assume that any practice effect would be negligible after 6 months.

The "index of reliability" of the analysis to secure the experiments was arbitrarily defined as the quotient obtained by dividing the total number of experiments *common* to the two lists secured from the two analyses of the same source materials by the total number of *different* experiments obtained from the two analyses. Accordingly, the "index of reliability" of the analysis to secure the experiments was the quotient obtained by dividing A, the number of experiments common to the two lists, by D, the total number of different experiments obtained. $D = A + B + C$, where A is the number of experiments common to the two lists, B is the number of experiments found in the first analysis that were not found in the second, and C is the number of experiments found in the second analysis that were not found in the first. The figures for A, B, and C were: A, 58; B, 1; C, 1. Therefore, the "index of reliability" of the analysis to secure the experiments was 0.97 which was assumed to be sufficiently high.

Validity

An attempt was then made to secure a measure of the validity of the analysis to secure the experiments. Fifty experiments, representing together those found in the different types of the sources analyzed, were selected at random. The purpose of each of the 50 and the source, or sources, from which each was taken or derived were written on individual white cards. The purpose was written in the form of a question. A specialist in the teaching of science then read for each experiment the purpose written on the card, and also the directions for its performance as they appeared in the original source, or sources. He indicated for each on a check list that the question as stated on the card was or was not, in his opinion, a correct statement of the purpose of the experiment.

Fifty experiments were considered in this manner. The specialist and the investigator were in agreement on all 50. It, therefore, seemed reasonable to assume that the validity of the analysis to secure the experiments was sufficiently high.

Method of Assigning Experiments to Principles

The second minor problem was to assign the assembled experiments to the various principles of physical science. These experiments were assigned by the investigator, wherever possible, to the 214 principles which had previously been given positive

values by all the judges as a means of indicating their appropriateness for inclusion in an integrated course of physical science for senior high school. The *criterion* on the basis of which each assignment was made was that the performance of the experiment must be contributory to the development of an understanding of the principle.

When an experiment was assigned to more than one principle, duplicates of the original card for that experiment were made and so assigned. The number of each principle to which an experiment was assigned was written across the top of each new card. The number in the upper right corner of each card always designated the principle to which that card and its experiment was assigned.

Twenty-five hundred different assignments of experiments to principles were thus made. Some experiments were assigned to as many as 16 principles.

Reliability

It seemed likely that there might be some variability in the assignments of the experiments to the principles if the assignments were made again, especially at a considerably later time. It was, therefore, deemed necessary to determine an "index of reliability" for these assignments.

An assistant made two white cards for each of 50 different experiments which he selected at random from the twenty-five hundred assignments of experiments to the 214 principles. He wrote on one of these cards the purpose of an experiment, and, at the *top*, the individual numbers of all principles to which that experiment had been assigned by the investigator; and on the other only the purpose. After 9 months, during which time the cards were not seen by the investigator, the latter reassigned to the same 214 principles the 50 experiments on the cards which did not also have on them the numbers of the principles to which they had previously been assigned. The individual numbers of the different principles to which an experiment was assigned this second time were written across the *bottom* of the card, so that the cards of each pair would not subsequently be confused. The data on the two sets of cards showing the separate allocations for each of the 50 experiments were assembled into two lists for use in computing the "index of reliability." During the last 6 months of the 9 between the two assignments, the investigator had had no practice in assigning, or in evaluating the assignment of, experiments to principles.

The "index of reliability" was arbitrarily defined as the quotient obtained by dividing the total number of assignments *common* to the two lists resulting from twice assigning the same group of experiments to the same principles, by the total number of *different* assignments made in assigning the experiments twice. Accordingly, the "index of reliability" of the assignments of the experiments to the principles was the quotient obtained by dividing A, the number of assignments common to the two lists, by D, the total number of different assignments made. $D = A + B + C$, where A is the number of assignments common to the two lists, B is the number of assignments made the first time that were not made the second time, and C is the number of assignments made the second time that were not made the first time. The figures for A, B, and C were: A, 134; B, 2; C, 8. Therefore, the "index of reliability" of the assignments of the experiments to the principles was 0.93 which was assumed to be sufficiently high.

Evaluation of the Experiments

It was assumed that the degree to which the performance of the different experiments might reasonably be expected to be contributory to the development of an understanding of a principle, is an acceptable basis for determining the relative values of those experiments for inclusion in the course. It was further assumed that the use of the judgments of specialists in the teaching of science to determine the relative

values of the experiments, and to determine the appropriateness of an experiment for performance as a laboratory experiment or as a demonstration, is defensible.

The jury technique was employed for the evaluations. It was assumed that 4 would constitute an acceptable number of evaluators of the experiments. Three specialists in the teaching of science, in addition to the investigator, agreed to evaluate the experiments. All 4 specialists were well qualified in terms of their teaching experience and their subject-matter training.

A copy of the investigator's list of 214 principles, together with the experiments assigned to each of them, was submitted to each evaluator with the following explanations and instructions:

Submitted with this letter are 214 principles of physical science which were deemed by 5 specialists in the teaching of science to have some positive value for inclusion in an integrated course of physical science for senior high school. A subject-matter specialist in each of the fields of physics, chemistry, and geology has approved the principles in his respective field, for accuracy of statement. No attempt has been made to express the principles in a vocabulary suitable for use at the high-school level.

You will find assigned to most of the 214 principles one or more experiments which were included in textbooks and laboratory manuals intended for use in courses of physical science offered in senior-high schools. These courses have commonly been called physics, chemistry, physical science, earth science or physiography or physical geography, consumer science, senior science, or aeronautics. A few of the experiments came from unpublished Masters' theses and Doctors' dissertations which contained lists of experiments for use in the physical sciences at the senior-high-school level. An experiment was assigned to a principle whenever, in the opinion of the investigator, the performance of the experiment might reasonably be expected to be contributory to the development of an understanding of the principle.

The following letters and figures are to the right of each experiment:

N D L 1 2 3 4 5. Will you kindly mark each experiment according to the following directions:

"Please encircle the appropriate symbol to the right of each experiment to indicate, respectively, whether you consider that the performance of the experiment

N—would *not* be contributory to the development of an understanding of the principle to which it is assigned;

D—would be contributory and would more appriately be done as a *demonstration* experiment than as a laboratory experiment; or

L—would be contributory and would more appropriately be done as a *laboratory* experiment than as a demonstration experiment.

"If you consider the experiment to be equally appropriate for demonstration and laboratory purposes please encircle both the D and the L.

"The experiment should be marked as being more appropriately done as a demonstration (D) than as a laboratory experiment, if

1. The experiment involves an element of danger when performed unskilfully.
2. The experiment involves very difficult and detailed manipulation.
3. The experiment requires too much time for its successful performance by pupils in terms of the values they might reasonably be expected to gain from doing the experiment.
4. The experiment involves very expensive apparatus and equipment.
5. The experiment is designed to acquaint the pupils with the apparatus and with acceptable techniques of experimentation.

Also, please encircle the appropriate symbol to the right of each experiment to indicate, respectively, whether you consider that the experiment

1—Is not at all suited for inclusion in an integrated course of physical science for senior high school; and for the development of an understanding of the principle;
2—Is poorly suited;
3—Is neither well nor poorly suited;
4—Is well suited; or
5—Is ideally suited for inclusion in such a course; and for the development of an understanding of the principle.

The criteria which delimit the purpose of the physical-science course and which therefore are to serve as bases for the judgments to be made by you on the scale of 1–5 are:

The integrated course of physical science for senior high school

(1) is planned to serve not only as a college-preparatory course but also as a terminal course for those capable of profiting by such a course; and

(2) is intended to accomplish for physical science the same purposes that are now served by a high-school course in general biology.

Additional criteria which are also to serve as bases for the judgments to be made by you on the scale of 1–5 are:

The experiment

(1) Must be simple enough for ready comprehension; and

(2) must be practicable within the time which is commonly available.

"If you do not encircle the N or the 1, please encircle the D or the L, or both the D and the L, and then a 2, 3, 4, or 5.

The following is an example* of a type of marking which may be made in accordance with the directions given.

Principle

No chemical change occurs without an accompanying energy change.

Experiment

Does magnesium ribbon burn with an intense white flame? N D L† 1 2 3 4 ⑤

The L was encircled because the experiment was considered more appropriately done as a laboratory experiment than as a demonstration. The 5 was then encircled because the experiment was considered to be ideally suited for inclusion in the course, and for the development of an understanding of the principle.

For the purposes of this evaluation, you are asked to adopt the following definitions of terms: [The terms physical science, integrated course of physical science, and senior high school as previously defined.]

After the list of experiments assigned to the principles had been marked by the 4 evaluators and returned, every experiment which had been marked by at least 2 of the 4 evaluators as being unsuited to the proposed course was eliminated. Moreover, every experiment which had been marked by one or more of the evaluators as not being contributory to the development of an understanding of the principle to which the investigator had assigned it was eliminated for that principle. Evaluations of the remaining experiments were tabulated for presentation in a table.

Validity

Since only 5 of the investigator's 2500 assignments of experiments to principles had been disapproved by one or more judges on the ground that they did not contribute to an understanding of the principle to which they had been assigned, it seems justifiable to assume that the validity of the method by which these assignments had been made was sufficiently high.

The complete report of the investigation contains a table in which the experiments allocated to each principle are ranked in descending order of their relative values for inclusion in an integrated course of physical science for senior high school and for the development of an understanding of the principle. That table is too voluminous to be included here. However, one of the 214 principles and some of the experiments assigned to it are presented in Table II which shows the nature of the table which appears in the complete report of the investigation.

* Four other examples given the evaluators are omitted from this article.

† L should be encircled.

FINDINGS

1. Twenty-five, or 11.7 per cent, of the 214 principles had no experiments assigned to them. Of the twenty-five, 7 had been deemed essential by all judges.

2. Eleven hundred seventy-seven assignments of experiments, which were defensibly made to 189 principles, were given positive values by the 5 evaluators for inclusion in an integrated course of physical science for senior high school.

3. Of the assignments of experiments which had been made to 34 of the 40 principles deemed essential by all the judges, 125 were considered by all the judges to be either ideally or well suited for inclusion in the course and for the development of an understanding of the principle, or principles, to which they had been assigned.

4. Of the assignments to the 103 principles to each of which an aggregate value of 13, 14, or 15 * had been assigned, 286 were deemed by all the judges to be either ideally or well suited. Thus, an average of 2.78 experiments was assigned to each of these highly valued principles.

5. Twenty of these 103 principles each had assigned to it at least one experiment which was deemed by every judge to be ideally suited for inclusion in the course and for the development of an understanding of the principle. Eighty-five of the 103 principles had from 1 to 14 experiments which were considered by every judge to be either

* In order for one of these principles to have received one of these values, at least 3 judges considered it to be essential; no more than 2 considered it merely desirable; and none of the 5 considered it undesirable.

TABLE II

THE RELATIVE VALUES AND RANKS OF LABORATORY AND DEMONSTRATION EXPERIMENTS ALLOCATED TO THE PRINCIPLES OF PHYSICAL SCIENCE DESIRABLE FOR INCLUSION IN AN INTEGRATED COURSE OF PHYSICAL SCIENCE FOR SENIOR HIGH SCHOOL

Experiments Allocated to Principles	Value	Rank	
Principles Deemed Essential by All Evaluators			
Principle Sound is produced by vibrating matter and is transmitted by matter.			
Experiments			
When sound is produced, must something be vibrating? What is observed when the tines of a tuning fork are struck and touched to the surface of water? Touched lightly to an ear or finger? Brought near a suspended pith ball? What is observed when the free end of a yard stick clamped to a desk is pulled and let go? When a tight string on a musical instrument is plucked? When fingers are held on the throat while the alphabet is pronounced?	20 *	1	L **
How is a soap film (ear drum) over the smaller end of a megaphone affected when the tone a-a-a-h is sounded in the larger end (outer ear)?	17	2	D
Does sound travel better through a gas or a solid? Is the sound of an automobile engine or electric motor carried to the ear better through an iron rod or air? When a spoon on a string is swung against a chair, is the sound carried to the ears best through the string, through air alone, or through the chair touched to a tooth?	15	3.5	L
If the tines of a table fork held on end on a table are compressed and suddenly released, can the vibration be heard?	15	3.5	X
Is the intensity of sound increased or decreased by increasing the amplitude of a vibrating body such as plucking a tightly stretched string and striking a tuning fork harder?	13	5.5	D
Is the intensity of a sound increased or decreased by increasing the area of the vibrating body such as holding the stem of a vibrating tuning fork on a chalk box and then on a table top?	13	5.5	D
Does sound travel better through a gas or a liquid? Is the tick of a watch heard better through a filled hot-water bottle held to the ear or through the same distance of air?	12	7	L
Do sounds travel better through some solids than through others? Are sounds of the voice carried better over a string or a wire between two tin cans? Can the ticking of a watch be heard better through a length of iron or a similar piece of wood when the ear and a watch are at opposite ends of the solid?	10	8	L

* The numerical values assigned to the experiments are the algebraic sums of the individual evaluations of the four judges on the scale of 1–5.

** The symbol L or D following a rank indicates, respectively, that the experiment was considered by the four evaluators as being more appropriately performed as a laboratory experiment or as a demonstration. X indicates equal appropriateness for either method.

ideally or well suited. Of these 85 principles, 61 had 2 or more assignments of such experiments, and 41 had 3 or more.

6. Of the 286 experiments judged to be ideally or well suited for inclusion in the course and for the development of an understanding of one or more of the 103 principles, 159, or 55.6 per cent, were deemed by 3 or more of the 4 judges to be more appropriately done as demonstrations than as laboratory experiments; 84, or 29.4 per cent, were deemed to be more appropriately done as laboratory experiments than as demonstrations; and 43, or 15.0 per cent, were judged to be equally appropriate for performance by either method. Comparable data for the 125 experiments assigned to the forty principles which had been deemed

essential by all judges were: 64, or 51.2 per cent, as demonstrations; 46, or 36.8 per cent, as laboratory experiments; and 15, or 12 per cent, as equally appropriate for performance by either method.

CONCLUSIONS

1. It is obvious that there is an abundant number of principles well suited for inclusion in the integrated course of physical science.

2. The data presented indicate that there is an abundance of experiments suitable for developing understandings of most of the principles, and for most of these principles there is a considerable choice of such experiments.

3. The fact that about two-thirds of the "important" principles were from the field of physics (including astronomy and meteorology); one-fourth from chemistry; and one-tenth from geology emphasizes the difficulty of providing a course which is well balanced among the different fields of the physical sciences. This statement emphasizes the necessity for the curriculum maker to make optimal use of those principles, different aspects of which can be developed by an assortment of experiments and of other materials provided from as many as possible of these different fields of physical science.

4. It should be noted that the number of experiments deemed by the judges to be more appropriately done as laboratory experiments rather than as demonstrations is more than half the number deemed more appropriately done as demonstrations (29.4 per cent laboratory as compared with 55.6 demonstration); and that the remaining 15 per cent were judged to be equally appropriate for performance by either method. It seems obvious, therefore, that the teacher has available an ample selection of experiments for use with either method.

5. It is likely that many of the experiments discovered, including those which were discarded as not being well suited to the development of understandings of principles, might, nevertheless, be indispensable and prove of great value for the development of skills in the use of the elements of scientific method, or the inculcation of scientific attitudes.

6. The 25 principles for which there were no experiments (primarily ones dealing with atomic structure and/or nuclear physics) present a challenge to those who are developing courses of physical science to devise experiments suitable for the inductive development of understandings of these principles.

RECOMMENDATIONS

1. Further studies should be made for the purpose of supplementing the lists of experiments useful in developing the understandings of the important principles of physical science. It is recognized, of course, that the problem of determining the important principles of physical science and the ways by which understandings of them may be developed can and should be attacked with other techniques than those employed in this investigation.

2. The relatively small number of principles for the development of which the lists of experiments revealed by this study are limited, provides a major challenge to future workers, to increase and refine these lists.

REFERENCES

1. Miles, Vaden Willis. *A Determination of the Principles and Experiments Desirable for a High-School Course of Integrated Physical Science.* Unpublished Doctor's dissertation, University of Michigan, 1947. Pp. vii + 207. [Available through inter-library loan from University of Michigan Library, Ann Arbor, Michigan; distributed in microfilm form by University Microfilm, Ann Arbor, Michigan.]
2. *The Publisher's Trade List Annual, 1945.* New York: R. R. Bowker Co., 1945.

SUPPLEMENTARY CONTRIBUTIONS OF SOUND MOTION PICTURES IN HIGH SCHOOL BIOLOGY *

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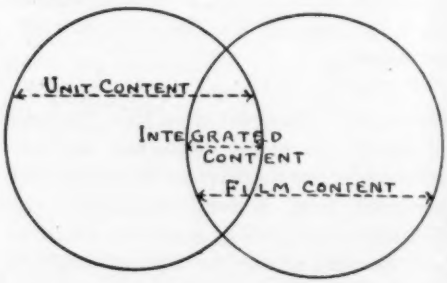
THE PROBLEM

SEVERAL research studies have shown that the use of carefully selected sound motion pictures as an integral part of the learning activities which together constitute a unit of instruction in science may produce a significant increase in the resulting learning as measured by tests covering the outcomes of the unit as a whole.[1, 2] As might be expected, there is evidence which indicates that the contribution of films increases as the degree of integration of films and unit content increases.[3] Thus complete integration or overlapping of film content with facts and principles emphasized by other methods used during the study of a unit seems desirable. However, since in actual practice films are usually selected to fit a unit rather than the unit being organized about certain films, this degree of integration can rarely be attained. More frequently the content of films selected for use with a unit includes some materials which overlap the usual unit activities and also other materials which supplement rather than duplicate or re-emphasize concepts included in the unit. This condition may be illustrated diagrammatically by two overlapping circles representing, respectively, unit content and film content.



Since most of the research associated with the use of sound motion pictures in science teaching has utilized evaluative instruments based upon unit content, what has really been evaluated is the effect of the overlapping of film content on unit content. The segment of the circle representing film content which extends to the right beyond the circle representing unit content may be regarded as representing supplementary material not otherwise taught during the study of a unit. If the films have been carefully selected in terms of their potential contribution to unit content and if the individual films themselves possess unity, this supplemental material should be desirable from the point of view of course enrichment.

The amount which a film may thus contribute to course enrichment will obviously vary from film to film and will in all cases be conditioned by the scope of organization of the unit with which the film is used and by the variety of instructional materials

* The raw data upon which this report is based constitute a minor fraction of data collected during the progress of The Nebraska Program of Educational Enrichment Through Use of Motion Pictures. These data have been released to the writer for use in the present report by the Program Director with the approval of the Executive Committee. A complete report of the outcomes of this Program will be published at a later date. The writer has been associated with the Program, during the past two years, as Director for the University of Nebraska area. Paper presented on program of The National Association for Research in Science Teaching, New York City, February 15, 1949.

[1] Arnspiger, Varney C., *Measuring the Effectiveness of Sound Pictures as Teaching Aids*, Contributions to Education, No. 565, Teachers College, Columbia University, New York, 1933.

[2] Rulon, P. J., *The Sound Motion Picture in Science Teaching*, Harvard University Press, Cambridge, Massachusetts, 1933.

[3] Jayne, C. D., "Visual Aids in the Classroom," *Journal of Experimental Education*, Vol. V, No. I, pp. 7–17, Sept., 1936.

available for use within a school. The investigation herein reported was undertaken in order to reveal the extent to which films ordinarily available for use in high school biology classes contribute enrichment materials beyond the usual scope of the course as taught in selected group of the larger Nebraska high schools.

THE METHOD

The cooperation of five Nebraska high schools was secured in each of which two or more sections of biology were taught by the same instructor. Through personal visitation of the investigator or of an associate pre-experimental conferences were held with each instructor. During these conferences the biology curriculum as planned for the second semester, 1946–47, was studied and five biology films were selected which could be integrated with the curriculum in each school. A sufficient number of prints of each of these films was secured to permit the scheduling of each film in each school for a six-day period at that point in the course at which its content best fit the planned curriculum.

During these and later conferences with cooperating instructors plans were also made for the use of a uniform method of film utilization. This method involved, (1) the preview of the film by the instructor, (2) a pre-film discussion designed to direct the observation of pupils to important concepts presented by the film, (3) the showing of the film, (4) a period of post-film discussion, and (5) the re-showing of the film. Thus, approximately two periods of class time were to be used during the study of each film.

Films selected for use in the experiment were each produced by Encyclopaedia Britannica Films, Inc. and included the following: "Reactions in Plants and Animals," "Flowers at Work," "Body Defenses Against Disease," "The Nervous System," "Heredity," "Reproduction Among Mammals," and "Endocrine Glands."

Following the selection and scheduling of films, eight multiple choice test items were constructed based upon the content of each film which had been selected. These items were combined into a fifty-six item test instrument which it was assumed would validly measure knowledge of facts and concepts developed by the seven films. As an example of the nature of this test one item has been selected at random from the eight associated with each film. These test items follow:

1. A worm when placed in a strong electrical field, (1) will turn so that its head points toward the positive pole and its tail toward the negative pole, (2) will turn so that its head points toward the negative pole and its tail toward the positive pole, (3) will be unaffected by the field, (4) will turn both ends away from the positive pole, (5) will turn both ends away from the negative pole.
2. Flowers which belong to the composite family, (1) always have a total of three anthers, (2) are always adapted to easy self fertilization, (3) have a total of five anthers which are united in a ring and fastened to the petals, (4) have a head which consists of five small separate flowers clustered together.
3. The function of lymph nodes in the human body is to, (1) replenish the supply of red blood corpuscles, (2) regulate the movement of lymph throughout body tissues, (3) engulf and devour bacteria carried by the lymph, (4) replenish the supply of lymph fluid.
4. The magnitude or strength of a nerve impulse, (1) is independent of the strength of the stimulus that started it, (2) is directly proportional to the strength of the stimulus that started it, (3) is independent of the condition of the nerve through which it travels.
5. The number of chromosomes present in the sperm or egg cells of any individual is, (1) only one half as great as the number of chromosomes present in the body cells of the same individual, (2) twice as great as the number present in the body cells of the same individual, (3) exactly the same as the number present in the body cells of the same individual.
6. During the period of early development of a fertilized egg cell, the gastrula stage is that stage in which, (1) the group of cells has assumed the shape of a hollow ball, (2) a single layer of cells have developed, (3) both an inner and outer layer of cells have developed, (4) three distinct cell layers have been formed.
7. There is experimental evidence to indicate that thyroid deficiency results in (1) abnormally slow utilization of oxygen by the body, (2) abnormally rapid utilization of oxygen by the body, (3) an abnormal increase in the sugar

content of the blood, (4) an abnormal decrease in the calcium content of the blood.

The reliability of this film test was secured from the results of the administration of the test to an independent group of 311 biology pupils at the close of the school year 1946–47. Utilizing the split-halves technique and the Spearman-Brown formula the predicted reliability of the fifty-six item test was found to be .64. This reliability is sufficiently high to justify use of the test in making group comparisons.[4]

At the beginning of the second semester 1946–47, both the Film Test and the Cooperative Biology Test, Form P, 1939, were administered to all biology pupils in all five cooperating schools. During this semester each of the five cooperating teachers taught one section of biology as a control group and one or more sections as experimental groups. The only difference between experimental and control group methods was that control groups did not observe films but spent the time which might have been given to film usage in more complete utilization of other learning activities. At the close of the semester both the Film and Cooperative Tests were again administered to all experimental and control groups.

[4] Garrett, Henry E., *Statistics in Psychology and Education*, Longmans, Green and Co., New York, 1938, p. 314.

STATISTICAL ANALYSIS OF RESULTS

The method of analysis of covariance was used to evaluate the differences between control (non-film) and experimental (film) groups as revealed by both Cooperative and Film Test scores. This method provides both for the statistical adjustment or equating of experimental and control groups on the basis of the regression of final on initial class means, and for the elimination of variability due to school differences.

TABLE I

STANDARDIZED TEST

TOTALS AND MEANS OF INITIAL SCORES (X)

	Control		Experimental		Schools		Number of
School	Totals	Means	Totals	Means	Totals	Means	Pupils
1	1527	56.56	1299	48.11	2826	52.33	54
2	1423	64.68	1052	47.82	2475	56.25	44
3	816	54.40	836	55.73	1652	55.07	30
4	600	40.00	559	37.27	1159	38.63	30
5	781	37.19	688	32.76	1469	34.98	42
Methods	5147	51.47	4434	44.34	9581	47.90	200

$GM_x = 47.90$ $GT_x \cdot GM_x = 9581 \times 47.90 = 458{,}930$

TABLE II

STANDARDIZED TEST

TOTALS AND MEANS OF FINAL SCORES (Y)

	Control		Experimental		Schools		Number of
School	Totals	Means	Totals	Means	Totals	Means	Pupils
1	1790	66.30	1488	55.11	3278	60.70	54
2	1589	72.23	1232	56.00	2821	64.11	44
3	1106	73.73	1142	76.13	2248	74.93	30
4	1069	71.27	847	56.47	1916	63.87	30
5	957	45.57	827	39.38	1784	42.48	42
Methods	6511	65.11	5536	55.36	12047	60.23	200

$GM_y = 60.23$ $GT_y \cdot GM_y = 12047 \times 60.23 = 725{,}591$

TABLE III

STANDARDIZED TEST

SUM OF SQUARES FOR METHODS, SCHOOLS, CLASSES, AND M × S

INITIAL SCORES (X)

School	Methods: Control	Methods: Experimental	T_s	$\Sigma T_c^2/N_c$	T_s^2/N_s	N_s	N_c
1	1527	1299	2826	148856.66	147894.00	54	27
2	1423	1052	2475	142347.00	139218.75	44	22
3	816	836	1652	90983.47	90975.64	30	15
4	600	559	1159	44832.07	44772.17	30	15
5	781	688	1469	51490.71	51385.62	42	21
T_m	5147	4434	$9581 = GT$			$200 = N$	
Methods Means	51.47	44.34	$GM \cdot GT = GT^2/N = 9581^2/200 = 458{,}930$				

A. Sum of squares for methods $= \Sigma T_m^2/N_m - GT^2/N$
$= 2589.65$

B. Sum of squares for schools $= \Sigma T_s^2/N_s - GT^2/N$
$= 15316.18$

C. Sum of squares for classes $= \Sigma(\Sigma T_c^2/N_c) - GT^2/N$
$= 19{,}579.91$

D. Sum of squares for M × S $= C - B - A$
$= 1674.08$

TABLE IV

STANDARDIZED TEST

SUM OF SQUARES FOR METHODS, SCHOOLS, CLASSES, AND M × S

FINAL SCORES (Y)

School	Methods: Control	Methods: Experimental	T_s	$\Sigma T_c^2/N_c$	T_s^2/N_s	N_s	N_c
1	1790	1488	3278	200675.70	198974.60	54	27
2	1589	1232	2821	183761.14	180854.31	44	22
3	1106	1142	2248	168493.33	168442.64	30	15
4	1069	847	1916	124011.33	122374.92	30	15
5	957	827	1784	76179.90	75784.32	42	21
T_m	6511	5536	$12047 = GT$			$200 = N$	
Methods Means	65.11	55.36	$GM \cdot GT = GT^2/N = 12047/200 = 725{,}591$				

A. Sum of squares for methods $= \Sigma T_m^2/N_m - GT^2/N$
$= 4813.17$

B. Sum of squares for schools $= \Sigma T_s^2/N_s - GT^2/N$
$= 20{,}839.79$

C. Sum of squares for classes $= \Sigma(\Sigma T_c^2/N_c) - GT^2/N$
$= 27{,}530.40$

D. Sum of squares for M × S $= C - B - A$
$= 1877.53$

In order for the method to be valid it is necessary: (1) that the number of pupils in control and experimental groups within each school must be equal; and (2) that the regression of final on initial means, with methods and school differences eliminated, should be linear and approximately constant. The first of these conditions was met by discarding randomly selected scores from either the control or experimental dis-

TABLE V

STANDARDIZED TEST

SUM OF PRODUCTS FOR METHODS, SCHOOLS, CLASSES AND M × S

A. Sum of Products for Methods $= \Sigma(T_{m,x} \cdot M_{m,y}) - GT_x \cdot GT_y/N$
Where $T_{m,x}$ = Methods total (x), and
$M_{m,y}$ = Corresponding methods mean (y).
$= 3475.88$

B. Sum of Products for Schools $= \Sigma(T_{s,x} \cdot M_{s,y}) - GT_x \cdot GT_y/N$
Where $T_{s,x}$ = School total (x), and
$M_{s,y}$ = Corresponding school mean (y).
$= 13{,}311.73$

C. Sum of Products for Classes $= \Sigma(T_{c,x} \cdot M_{c,y}) - GT_x \cdot GT_y/N$
Where $T_{c,x}$ = Class total (x), and
$M_{c,y}$ = Corresponding class mean (y).
$= 18{,}232.45$

D. Sum of Products for M × S $= C - B - A$
$= 1{,}444.84$

TABLE VI

STANDARDIZED TEST

SIGNIFICANCE OF ADJUSTED METHODS DIFFERENCES

Summary of Data	ΣX^2	ΣXY	ΣY^2
M	2589.65	3475.88	4813.17
M × S	1674.08	1444.84	1877.53
M + M × S	4263.73	4920.72	6690.70

A. Adjusted Sum of Squares for M × S $= \Sigma Y^2 - (\Sigma XY)^2/\Sigma X^2$
$= 630.63$

B. Adjusted Sum of Squares for M + M × S $= \Sigma Y^2 - (\Sigma XY)^2/\Sigma X^2$
$= 1012.19$

C. Reduced Sum of Squares for M $= B - A = 381.56$

D. Methods Variance $=$ C/d f. for methods $= 381.56/1$
$= 381.56$

E. Adjusted M × S (error) Variance $=$ A/d.f. for error variance
$= 630.63/3 = 210.21$
$F = D/E = 1.83$

F, required for significance at 1% level = 34.12
at 5% level = 10.13

TABLE VII

FILM TEST

TOTALS AND MEANS OF INITIAL SCORES (X)

	Control		Experimental		Schools		Number of
School	Totals	Means	Totals	Means	Totals	Means	Pupils
1	442	16.27	463	17.15	905	16.76	54
2	291	13.23	300	13.64	591	13.43	44
3	273	18.20	267	17.80	540	18.00	30
4	216	14.40	178	11.87	394	13.13	30
5	359	17.10	353	16.81	712	16.95	42
Methods	1581	15.81	1561	15.61	3142	15.71	200

$GM_x = 15.71$ $\qquad GT_x \cdot GM_x = 3142 \times 15.71 = 49{,}361$

TABLE VIII

FILM TEST

TOTALS AND MEANS OF FINAL SCORES (Y)

School	Control		Experimental		Schools		Number of Pupils
	Totals	Means	Totals	Means	Totals	Means	
1	729	27.00	841	31.15	1570	29.07	54
2	517	23.50	584	26.55	1101	25.02	44
3	473	31.53	563	37.53	1036	34.53	30
4	370	24.67	414	27.60	784	26.13	30
5	390	18.57	456	21.71	846	20.14	42
Methods	2479	24.79	2858	28.58	5337	26.685	200

$Gm_Y = 26.685$ $\qquad GT_Y \cdot GM_Y = 5337 \times 26.685 = 142{,}418$

TABLE IX

FILM TEST

SUM OF SQUARES FOR METHODS, SCHOOLS, CLASSES, AND M × S

INITIAL SCORES (X)

School	Methods		T_s	$\Sigma T_c^2/N_c$	T_s^2/N_s	N_s	N_c
	Control	Experimental					
1	442	463	905	15175.30	15167.13	54	27
2	291	300	591	7940.05	7938.20	44	22
3	273	267	540	9721.20	9720.00	30	15
4	216	178	394	5222.67	5174.53	30	15
5	359	353	712	12070.95	12070.10	42	21
T_m	1581	1561	$3142 = GT$			$200 = N$	
Methods Means	15.81	15.61					

$GM \cdot GT = GT^2/N = 3142^2/200 = 49{,}361$

A. Sum of squares for methods $= \Sigma T_m^2/N_m - GT^2/N$
$= 1.82$

B. Sum of squares for schools $= \Sigma T_s^2/N_s - GT^2/N$
$= 708.96$

C. Sum of squares for classes $= \Sigma(\Sigma T_c^2/N_c) - GT^2/N$
$= 769.17$

D. Sum of squares for M × S $= C - B - A$
$= 58.39$

tributions within each school until the number of scores in each distribution was equal. Conformity to the second condition was then checked by "correcting" both initial and final class means so as to eliminate methods and school differences and plotting final against initial "corrected class means." The resulting graphs (one for each test) gave clear evidence of linearity between final and initial means and showed only minor deviations from a constant relationship. For the purpose of brevity the details of these procedures have not been included in this report.

The techniques and computational procedures utilized in the analysis of data have followed methods and examples presented by Lindquist.[5] Tables I to VI inclusive, present the analysis of Standardized (Cooperative) Test scores, while Tables VII to XII inclusive, present a similar treatment of Film Test scores.

It will be noted (Table VI) that the F test for the significance of adjusted methods differences as revealed by the standardized

[5] Lindquist, E. F., *Statistical Analysis in Educational Research*, Houghton Mifflin Company, Chicago, 1940, Chapter VI.

TABLE X

FILM TEST

SUM OF SQUARES FOR METHODS, SCHOOLS, CLASSES, AND M × S

FINAL SCORES (Y)

School	Methods: Control	Methods: Experimental	T_s	$\Sigma T_c^2/N_c$	T_s^2/N_s	N_s	N_c
1	729	841	1570	45878.59	45646.30	54	27
2	517	584	1101	27652.05	27550.02	44	22
3	473	563	1036	36046.53	35776.53	30	15
4	370	414	784	20553.07	20488.53	30	15
5	390	456	846	17144.57	17040.86	42	21
T_m	2479	2858	5337 = GT			200 = N	
Methods Means	24.79	28.58	GM · GT = $GT^2/N = 5337^2/200 = 142{,}418$				

A. Sum of squares for methods $= \Sigma T_m^2/N_m - GT^2/N$
$= 718.05$

B. Sum of squares for schools $= \Sigma T_s^2/N_s - GT^2/N$
$= 4{,}084.24$

C. Sum of squares for classes $= \Sigma(\Sigma T_c^2/N_c) - GT^2/N$
$= 4{,}856.81$

D. Sum of squares for M × S $= C - B - A$
$= 54.52$

TABLE XI

FILM TEST

SUM OF PRODUCTS FOR METHODS, SCHOOLS, CLASSES AND M × S

A. Sum of Products for Methods $= \Sigma(T_{m,x} \cdot M_{m,y}) - GT_x \cdot GT_y/N$
Where $T_{m,x}$ = Methods total (x), and
$M_{m,y}$ = Corresponding methods mean (y).
$= -37.90$

B. Sum of Products for Schools $= \Sigma(T_{s,x} \cdot M_{s,y}) - GT_x \cdot GT_y/N$
Where $T_{s,x}$ = School total (x), and
$M_{s,y}$ = Corresponding school mean (y).
$= 532.00$

C. Sum of Products for Classes $= \Sigma(T_{c,x} \cdot M_{c,y}) - GT_x \cdot GT_y/N$
Where $T_{c,x}$ = Class total (x), and
$M_{c,y}$ = Corresponding class mean (y).
$= 515.66$

D. Sum of Products for M × S $= C - B - A$
$= 21.56$

biology test falls short of the magnitude required for significance at either the 1% or 5% levels. However, the slight difference suggested by the small value of F favors the control group. In contrast, the F test relating to differences based on the Film Test (Table XII) indicates complete significance at the 1% level in favor of the experimental group. The results of the analysis therefore indicate that pupils with whom films were utilized did at least equally as well on the standardized

TABLE XII

FILM TEST

SIGNIFICANCE OF ADJUSTED METHODS DIFFERENCES

Summary of Data	ΣX^2	ΣXY	ΣY^2
M	1.82	−37.90	718.05
M × S	58.39	21.56	54.52
M + M × S	60.21	−16.34	772.57

A. Adjusted Sum of Squares for M × S $= \Sigma Y^2 - \Sigma XY^2/\Sigma X^2 = 46.56$

B. Adjusted Sum of Squares for M + M × S $= \Sigma Y^2 - (\Sigma XY)^2/\Sigma X^2 = 768.14$

C. Reduced Sum of Squares for M $= B - A = 721.58$

D. Methods Variance $= C/\text{d.f. for methods} = 721.58/1 = 721.58$

E. Adjusted M × S (error) Variance $= A/\text{d.f. for error variance} = 46.56/3 = 15.52$

$F = D/E = 46.49$

F, required for significance at 1% level = 34.12
at 5% level = 10.13

test as pupils who did not observe films, and were definitely superior in their knowledge of facts and concepts presented by films as measured by the Film Test.

It will be recalled that the method of film utilization required approximately two class periods of time for the study of each film or fourteen class periods for the seven films. On the other hand, other methods of instruction were continued in control classes during these fourteen periods. When the experimental results are considered in terms of these conditions it appears that the films must have contributed to pupil growth in two ways: (1) as an equivalent substitute for other learning activities used with control classes during fourteen periods of class work, and (2) as a means of presenting facts and concepts not taught by other methods of instruction.

CONCLUSION

Stated in general terms the results of this investigation may be summarized as follows:

The use of a reasonable number of sound motion pictures which are closely related to the content of a semesters work in high school biology may materially enrich, or add to, pupil learning as measured by tests administered at the end of the semester, without detracting from normal pupil accomplishment as measured by a valid and reliable standardized test also administered at the end of the semester.

A DETERMINATION OF THE RELATIVE EFFECTIVENESS OF SOUND MOTION PICTURES AND EQUIVALENT TEACHER DEMONSTRATIONS IN NINTH GRADE GENERAL SCIENCE *

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THE USE of audio-visual materials as supplemental aids to instruction continues to show vigorous growth and development. This fact is undoubtedly the result of many diverse causes but two of the more obvious reasons are probably to be found in, first, the impetus provided by the wide spread usage of such materials during World War II and, secondly, recognition of the general inefficiency of purely verbal instruction with large numbers of pupils.

Many researches have been conducted for the purpose of finding solutions to the multitudinous problems which have presented themselves to educational workers in the field of audio-visual instruction. The cost of audio-visual aids, relative values of different methods of utilization, amount and retention of learning, and many other problems have been rather exhaustively examined. It seems rather remarkable, however, that research workers have not investigated the comparative merits of different audio-visual aids extensively. In relation to this deficiency Goodman has stated:

> A study of previous research in the field of visual education fails to reveal conclusive evidence that any one form of visual aid is more effective than another. The several studies reported . . . do reveal that visual media do make significant contributions to the learning process; but research evidence showing conclusively the comparative effectiveness of the sound motion picture, silent motion picture, sound film slide, or silent film slide is practically non-existent.[1]

To Goodman's statement it might well be added that comparisons between motion pictures, experimental demonstrations, and other modes of visual presentation are also without adequate representation in the literature.

In still another area the results of research have been somewhat contradictory. This area pertains to the relationship which exists between instructions utilizing various visual aids and the learning resulting with pupils at the different levels of intelligence. The following problem is primarily related to the comparative effectiveness of two methods of visual presentation and secondarily concerned with the relationship existing between the methods of presentation and intelligence.

THE PROBLEM

Specifically stated the problem investigated in this study is: What is the relative effectiveness in ninth grade general science classes of experimental demonstrations performed by the teacher and equivalent demonstrations presented through the medium of educational sound motion pictures? A closely related but subsidiary problem involved the determination of the relative effectiveness of these two instructional techniques with pupils of different levels of intelligence.

GENERAL PLAN OF THE STUDY

Dale and others have made a thorough analysis of sixty-one experimental studies and isolated seven typically neglected factors in much of the reported research in this area.[2] Briefly paraphrased these neglected factors are:

* Based on doctoral dissertation completed at the University of Nebraska, 1948. Presented on the program of the National Association for Research in Science Teaching, New York City, February 15, 1949.

[1] David J. Goodman, "Comparative Effectiveness of Pictorial Teaching Aids," *Journal of Experimental Education*, XII (September, 1943), p. 21.

[2] Edgar Dale, et. al., *Motion Pictures in Education*, (New York: H. W. Wilson Company, 1937), pp. 181–182.

1. Failure to use typical classroom procedure in teaching materials and too limited a time for instruction.
2. Lack of comparability of methods of instruction.
3. Poor methods of evaluation including failure to consider the objectives of instruction.
4. Failure to really equate control and experimental groups.
5. Insufficient analysis of data.
6. Diversity of grade classification in the same experiment.
7. Incomplete investigation of problems.

In the plan of the present study every effort was made to avoid neglect of these factors. The manner in which these and other factors were considered will, it is believed, become obvious in the following discussion.

In planning the study, it was contemplated that the experimentation would be conducted in as nearly a normal classroom situation as could be provided. It was also decided that the teaching value of the film and teacher demonstrations should be determined separately and combined which gave three different modes of presentation, or "methods." Five public schools meeting the requirements of the study consented to cooperate.

The experiment was designed in such a manner as to minimize the effects of variables other than the experimental factors. The following steps were taken to control the extraneous variables. All five schools cooperating in the study offered a minimum of three sections of ninth grade general science, all taught by the same teacher. This eliminated the teacher variable within a single school. Furthermore, the investigation was extended to include three different subject matter units in general science in order to compensate for the chance that a particular method might be peculiarly better fitted for use than another method on a single given unit.

As a further control, a rotation plan for methods among the three sections was followed in each school to compensate for chance section variations tending to favor one method or another. Since there were three methods, three experimental sections in each school, and three units of instructional materials, it was possible to devise a plan of rotation in which every section was eventually taught by each method on the successive units. Every student was taught by each of the three methods but had no method of instruction more than once. The method which a student might have on any particular unit was entirely a matter of chance.

Experimental Procedure

The experiment was conducted during the second semester of the school year 1947–48. During the first semester plans were drawn and preliminary conferences were held with all cooperating teachers. During the conference, the general plan of the investigation was explained and the requirements in terms of time and equipment were considered. Following the conference, a written statement of the general plan was distributed to cooperating teachers for their future reference.

Three films were selected on the subjects of magnetism, simple machines and properties of water which portrayed demonstrations readily duplicated by the classroom teachers. Units were constructed which were limited to the scope of the subject matter included in the film. This presented no difficulty because of the extensiveness and variety of principles covered in the sound motion pictures. These units were provided as guides for teachers and outlined in detail the demonstrations which were to be performed in classes taught by the demonstration method. Page references to several standard general science textbooks were included in the outline. Each unit was designed to require two to three weeks of classroom time.

In the three experimental classes used in the experiment in each school, all aspects of instruction were as nearly identical as possible except in the experimental fac-

tors. The experimental instructional methods used may be briefly described as follows: The film method section was taught by the educational sound motion picture in lieu of teacher demonstrations of any kind. In the demonstration section, no films were used. Demonstrations corresponded as exactly as possible to those shown in the film. Both the film and teacher demonstrations were used in the third sections; thus, students in this section had the benefit of both instructional techniques.

It should be borne in mind that both films and teacher demonstrations were regarded throughout the study as aids to instruction in the units and constituted merely a subordinate aspect of a more diverse and complex organization, i.e., the total teaching situation. The experiment was designed in this manner because it seems logical that visual aids will and should play exactly this role in any normal classroom situation.

EVALUATIVE INSTRUMENTS

The California Test of Mental Maturity was administered by the writer to all students participating in the study. In addition, objective, multiple-choice type tests were constructed over each of the three experimental units. Each test consisted of fifty items. Each item of the tests was carefully considered by a jury of competent persons interested in science education. Items were revised, reworded or discarded in accordance with their recommendations and suggestions. Since ninety separate administrations of the tests were required it was necessary that the classroom teachers administer the unit tests. Explicit and detailed directions were given for the test administration. All scoring was done by the writer. Because of the difficulty of building equivalent forms, the same unit tests were administered just prior to and immediately following the teaching of the experimental units. A statistical analysis of the scores thus obtained was made to determine the relative effectiveness of the three methods.

STATISTICAL PROCEDURE

The unit test reliabilities were determined by the split-half method and stepped up to give full length reliabilities by use of the Spearman-Brown formula.[3] As a check on the unit tests this same technique was applied to the scores from the California Test of Mental Maturity. The total correlation obtained on this test was .83 as compared to a value of .93 given by the test authors using the same method of determination. The predicted total correlation of the units tests was .78, .75, and .85 which compares favorably with the value obtained on the mental test and indicates the generally high reliabilities of the unit tests.

Lindquist has shown that the computation of test reliabilities from samples which contain intact school groups is a doubtful procedure unless the effect of school differences is eliminated.[4] The technique of analysis of covariance may be used for the purpose of eliminating the effect of school differences and gives a value which may be designated as a "within schools" reliability.[5] The reliabilities obtained from the total sample without regard to school differences and the "within schools" reliabilities are shown in Table I. In every case the elimination of school differences lowered the test reliabilities.

Between test correlations were computed and constituted one test for methods differences since each of the three sets of paired scores for any student was made on unit tests over units taught by different methods. These correlations were corrected for attenuation and compared with the indices of reliability of the unit tests. The results are shown in Table II. It will be noted that two of the corrected correlations are nearly as high as the corresponding indices of relia-

[3] Henry E. Garrett, *Statistics in Psychology and Education*, (New York: Longmans, Green and Company) p. 315.

[4] E. F. Lindquist, *Statistical Analysis in Educational Research*, (Boston: Houghton Mifflin Company, 1940), pp. 221–228.

[5] *Ibid.*

TABLE I

Total and Within Schools Self-Correlations

Test	Total Correlations: Between Halves	Total Correlations: Predicted reliability of entire test	Within Schools Correlations: Between Halves	Within Schools Correlations: Predicted reliability of entire test
Properties of H_2O	.65	.78	.50	.67
Simple Machines	.60	.75	.58	.73
Magnetism	.74	.85	.65	.79

This table should be interpreted thus: The correlations between halves of the final test on "Properties of H_2O" without elimination of school differences was .65. Stepped up to twice length by the Spearman-Brown Formula this becomes .78. The correlation between halves of this same test with school differences eliminated was .50. Stepped up to twice length, this becomes .67.

TABLE II

Inter-Test Correlations Corrected for Attenuation and Test Reliabilities with Corresponding Index of Reliability

Tests	Obtained Total Inter-Test Correlations	Correlations Corrected for Attenuation	Test Reliabilities	Index of Reliability
Simple Machines			.75	.86
Properties of H_2O	.63	.82	.78	.88
Magnetism			.85	.92
Properties of H_2O	.43	.53	.78	.88
Simple Machines			.75	.86
Magnetism	.65	.81	.85	.92

This table should be interpreted thus: The inter-test correlation between tests on "Properties of H_2O" and "Simple Machines" is .63. Corrected for attenuation this becomes .82. The test reliabilities of "Simple Machines" and "Properties of H_2O" are .75 and .78, respectively, while the indices of reliability of these tests are .86 and .88, respectively.

bility and that the third shows marked positive relationship. This may be taken as evidence that the method differences, if any, do not influence to any considerable degree, the consistency of performance of individual students.

A more precise test for methods differences was made by use of the technique of analysis of covariance. The method of analysis of covariance provides a technique for equating experimental and control groups statistically in terms of the regression of final on initial means. This is done without the necessity of pairing experimental and control groups prior to the beginning of the experiment. In using this technique the total variance of school means may be analyzed into three components, i.e., the variance between schools, the variance between methods and a remainder or methods times schools variance usually designated as the error or interaction variance. After correcting the methods variance and the interaction or M $\times$ S variance for differences in initial class means and for school differences, the significance of the methods differences is determined by the ratio of the methods variance to the M $\times$ S variance. This is the standard F test of significance. The values of F obtained were, in every case, much lower than those required for significance, indicating that there were no real methods differences.[5] Tables III thru VIII show the

[5] *Ibid.*

TABLE III

MAGNETISM

TOTALS AND MEANS OF INITIAL SCORES (X) *

	Film		Demonstration		Integrated		Schools		Number of
School	Totals	Means	Totals	Means	Totals	Means	Totals	Means	Pupils
1	220	9.57	247	10.74	208	9.04	675	9.78	69
2	333	18.50	280	15.56	294	16.33	907	16.80	54
3	446	17.84	449	17.96	429	17.16	1324	17.65	75
4	423	15.11	414	14.79	509	18.18	1346	16.02	84
5	409	12.78	388	12.13	349	10.91	1146	11.94	96
Methods	1831	14.53	1778	14.11	1789	14.20	5398	14.28	378

$GM = 14.28$ $GT \cdot GM = 5398 \times 14.28 = 77083.44$

TABLE IV

MAGNETISM

TOTALS AND MEANS OF FINAL SCORES (Y) *

	Film		Demonstration		Integrated		Schools		Number of
School	Totals	Means	Totals	Means	Totals	Means	Totals	Means	Pupils
1	681	29.61	686	29.83	767	33.35	2134	30.93	69
2	451	25.05	468	26.00	478	26.56	1397	25.87	54
3	615	24.60	609	24.36	649	25.96	1873	24.97	75
4	564	20.14	589	21.04	738	26.36	1891	22.51	84
5	608	19.00	595	18.59	520	16.25	1723	17.95	96
Methods	2919	23.17	2947	23.39	3152	25.02	9018	23.86	378

$GM = 23.86$ $GT \cdot GM = 23.86 \times 9018 = 215169.48$

* These totals and means represent the values obtained after equating the class sizes within each school, i.e., after rejection of students' scores from the largest two of the three sections in order to have equal numbers of scores for each of the three methods in each school.

TABLE V

MAGNETISM

SUM OF SQUARES FOR METHODS, SCHOOLS, CLASSES, AND M × S

INITIAL SCORES (X)

	Methods							
School	Film	Demonstration	Integrated	T_s	$\Sigma T_c^2/N_c$	T_s^2/N_s	N_s	N_c
1	220	247	208	675	6637.96	6603.26	69	23
2	333	280	294	907	15318.06	15234.24	54	18
3	446	449	429	1324	23382.32	23373.01	75	25
4	423	414	509	1346	21764.50	21568.04	84	28
5	409	388	349	1146	13738.31	13680.37	96	32
T_m	1831	1778	1789	5398	80841.15	80458.92	378	126
Methods Means	14.53	14.11	14.20	$GM \cdot GT = 77083.44$				

A. Sum of squares for methods $= \Sigma T_m^2/N_m - GT^2/N$
$= 14.70$

B. Sum of squares for schools $= \Sigma T_s^2/N_s - GT^2/N$
$= 3375.48$

C. Sum of squares for classes $= \Sigma T_c^2/N_c - GT^2/N$
$= 3757.71$

D. Sum of squares for M × S $= 396.93$

TABLE VI

MAGNETISM

SUM OF SQUARES FOR METHODS, SCHOOLS, CLASSES, AND M × S

FINAL SCORES (Y)

	Methods							
School	Film	Demonstration	Integrated	T_s	$\Sigma T_c^2/N_c$	T_s^2/N_s	N_s	N_c
1	681	686	767	2134	66202.00	65999.36	69	23
2	451	468	478	1397	36161.61	36140.90	54	18
3	615	609	649	1873	46812.28	46775.05	75	25
4	564	589	738	1891	43202.17	42570.01	84	28
5	608	595	520	1723	31065.28	30924.26	96	32
T_m	2919	2947	3152	9018	223443.34	222409.58	378	126
Methods Means	23.17	23.39	25.02	GM · GT = 215169.48				

A. Sum of squares for methods $= \Sigma T_m^2/N_m - GT^2/N$
$= 231.10$

B. Sum of squares for schools $= \Sigma T_s^2/N_s - GT^2/N$
$= 7240.10$

C. Sum of squares for classes $= \Sigma T_c^2/N_c - GT^2/N$
$= 8273.86$

D. Sum of squares for M × S $= 802.66$

TABLE VII

MAGNETISM

SUM OF PRODUCTS FOR METHODS, SCHOOLS, CLASSES AND M × S

A. Sum of Products for Methods $= \Sigma(T_{m,x} \cdot M_{m,y}) - GT_x \cdot GT_y/N$
Where $T_{m,x}$ = Methods total (x), and
$M_{m,y}$ = Corresponding methods mean (y).
$= -8.38$

B. Sum of Products for Schools $= \Sigma(T_{s,x} \cdot M_{s,y}) - GT_x \cdot GT_y/N$
Where $T_{s,x}$ = School total (x), and
$M_{s,y}$ = Corresponding school mean (y)
$= -509.57$

C. Sum of Products for Classes $= \Sigma(T_{c,x} \cdot M_{c,y}) - GT_x \cdot GT_y/N$
Where $T_{c,x}$ = Class total (x), and
$M_{c,y}$ = Corresponding class mean (y).
$= -183.28$

D. Sum of Products for M × S $= 334.67$

computational procedure for the experimental unit on magnetism. The other units were treated in an identical manner.

The discrepancies in the findings of experimental studies on the relationship between intelligence and learning resulting from the use of motion pictures was previously pointed out. The relationship existing between intelligence, as measured by an intelligence test and learning as represented by the gain of final over initial scores on the unit tests, was determined by computing coefficients of correlation. The within schools correlation was computed between gain and intelligence for all film sections on each of the three units. It may be recalled that each of the five schools had one section taught by the film method on each unit and that the three experimental sections were rotated in each school so that

TABLE VIII

MAGNETISM

SIGNIFICANCE OF ADJUSTED METHODS DIFFERENCES

Summary of Data	Σx^2	Σxy	Σy^2
M	14.70	−8.38	231.10
M × S	396.93	334.67	802.66
M + M × S	411.63	326.29	1033.76

A. Adjusted sum of squares for M × S

$$\Sigma y^2 - \frac{(\Sigma xy)^2}{\Sigma x^2} = 520.48$$

B. Adjusted sum of squares for M + M × S

$$\Sigma y^2 - \frac{(\Sigma xy)^2}{\Sigma x^2} = 775.12$$

C. Reduced sum of squares for M

$$B - A = 254.64$$

D. Methods variance

$$\frac{C}{\text{df for methods}} = \frac{254.64}{2} = 127.32$$

E. Adjusted M × S (error) variance

$$\frac{A}{\text{df for error variance}} = \frac{520.48}{7} = 74.35$$

$$F = \frac{\text{methods variance}}{\text{M} \times \text{S (error) variance}} = \frac{127.32}{74.35} = 1.71$$

F required for significance at 1% level = 9.55

F required for significance at 5% level = 4.74

all sections had the film method once. Thus, all fifteen sections are represented in these correlations. However, each separate within schools correlation was computed from five sections, one from each school. Exactly the same procedure was used to compute the correlations between gain and intelligence in the demonstrations sections. The correlations obtained were small but positive in all cases and were remarkably consistent.

The z-transformation was utilized to determine whether or not the correlations differed significantly from zero.[7] In five cases, the correlations were found to differ significantly from zero, at the 5% level of confidence or better. One of the five cases exceeded the 1% level of confidence. The sixth case fell just below the 5% level.

[7] Albert E. Waugh, *Elements of Statistical Method*, (New York): McGraw-Hill Book Company, 1943), p. 401.

FINDINGS

1. The between tests correlations corrected for attenuation were nearly as high as the corresponding indices of reliability in the case of two of the three unit tests and showed a marked positive relationship in the third case, indicating that students performed consistently regardless of method, i.e., instructional methods did not markedly influence the relative positions of the students on final tests.
2. The technique of analysis of covariance revealed that there were no real methods differences, insofar as the tests used in this investigation are capable of determining whether true differences exist.
3. The gains made by students as a result of instruction in any unit are positively related to their intelligence

where intelligence is expressed in terms of an intelligence quotient. This is true for both demonstration and film methods in approximately equivalent degrees.

CONCLUSIONS

1. Educational sound motion pictures and teacher demonstrations are of equal merit as instructional devices in ninth grade general science when they include essentially the same materials insofar as merit can be determined by the techniques employed in this investigation. The use of either method singly is as effective as the combination of the two.
2. There is a tendency for increased intelligence as expressed in terms of an intelligence quotient to be accompanied by increased learning where learning is represented by the gain of final over initial test scores on the objective tests used in this investigation. The degree of relationship is independent of the method of instruction utilized indicating the same relative value for sound motion pictures and teacher demonstrations portraying essentially identical materials regardless of the level of intelligence of students.

THE CONSTRUCTION AND VALIDATION OF A TEST TO MEASURE CERTAIN ASPECTS OF SCIENTIFIC THINKING IN THE AREA OF FIRST YEAR COLLEGE PHYSICS *

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INTRODUCTION

Evaluation in the physical sciences in the past has been primarily centered in the area of factual information. Other objectives worthy of evaluation have been recognized but the construction and validation of instruments to measure these is a relatively difficult task.

During the last fifteen (15) to twenty (20) years increasing attention has been given to appraising one of these objectives, namely quality of thinking. As yet, there is no positive knowledge as to the best means of proceeding with this appraisal. Direct observation of behavior and anecdotal records offer very good possibilities, but with the average teaching load the time and energy required make these methods impractical for many teachers. It would, therefore, be highly desirable to be able to evaluate the quality of thinking by a paper and pencil objective type examination, if such is possible. Further, the results obtained from such an objective form test would be more easily subjected to a sharper analysis of the students' thinking than would be the results from an essay form.

This study represents one approach to evaluation of certain aspects of scientific thinking.

THE PROBLEMS OF THIS STUDY

The problems of this study were:

1. To construct a paper and pencil test, in objective form that will evaluate certain aspects of scientific thinking, using the area of a first year college course in physics.
2. To validate the test.

The first problem required (a) the identification of those independent abilities

* Based on doctoral thesis at Syracuse University, 1948. Presented on program of The National Association for Research in Science Teaching, New York City, February 14, 1949.

and behaviors that may be ascribed to scientific thinking, (b) the determination of the procedures to be followed and of the form to be employed in constructing the test.

Since much of the work involved in accomplishing the first problem was based on empirical reasoning, the second problem of validation required other sources of proof. Involved in this second problem were the ascertaining of the relationships between the aspects of scientific thinking, as measured by the test, and other factors as measured by tests of (a) intelligence, (b) recall of factual information, (c) reading ability and (d) interest. Also, the relationship was to be determined between scores on the scientific thinking test and teachers' estimates of the students' abilities in scientific thinking. Lastly, there was to be found the relationship between the students' free written responses in solving problems and their scores on the objective form of the scientific thinking test.

THE ASSUMPTIONS FROM WHICH THIS STUDY PROCEEDS

There were three (3) major assumptions from which this study proceeded.

1. There are a number of component and independent abilities involved in scientific thinking.

2. The abilities involved in scientific thinking may be related to, but are not identical with, abilities as measured by intelligence and by factual information tests.

3. The abilities associated with scientific thinking are capable of measurement by paper and pencil tests constructed in objective form.

A DESCRIPTION OF PROCEDURES

The procedures followed in this study were generally those as suggested by Troyer and Pace[1] (1) the formulation of objectives; (2) the defining of general objectives into terms of specific behaviors implied by them; (3) the identification of the sources of evidence that can be used in observing such behavior; (4) the developing of methods of getting the evidence wanted; (5) the interpreting the results gathered in the light of goals and objectives.

THE FORMULATION OF OBJECTIVES

The purposes of the study were as stated at the opening of this article.

THE DEFINING OF OBJECTIVES INTO SPECIFIC BEHAVIORS IMPLIED BY THEM

As a result of studying the research related to this problem, it became apparent that there was no complete agreement as to what types of mental processes or what abilities may be identified as separate entities characteristic of scientific thinking.

Of the various abilities listed as aspects of scientific thinking by many sources, the two that occurred most frequently were (1) ability to interpret data and (2) ability to apply principles. The interpretations of data required inductive reasoning—the formulation of generalizations. The applications of principles involved deductive reasoning—the explanation of the specific case from the general rule. With these considerations in mind, the above two abilities were selected.

The evaluation of a student's abilities in interpretation of data and application of principles required a further analysis to determine what behaviors would best reveal these abilities. As stated by Smith and Tyler,[2] ". . . a type of objective such as the development of effective methods of thinking may mean different things to different people. Only as 'effective methods

[1] Troyer, Maurice E. and Pace, C. Robert. *Evaluation in Teacher Education.* Washington, D. C.: The American Council on Education, 1944.

[2] Smith, Eugene R. and Tyler, Ralph W. *Appraising and Recording Student Progress,* Report of the Committee on Evaluation and Recording of the Commission on Relation of School and College of the Progressive Education Association. New York: Harper and Brothers, 1942.

of thinking' is defined in terms of the range of reactions expected of students can we be sure what is to be evaluated under this classification." Therefore, the following were proposed.

Interpretation of data: the general behaviors were recognizing (1) relationships and (2) limitation of data concerning physics materials. The specific behaviors were how frequently a student's interpretations were (1) accurate or in error, (2) overgeneralizations (going beyond the data), and (3) undergeneralizations (too cautious).

Application of principles: the general behavior was the application of principles of physics to the solutions of problems. The specific behaviors were (1) the identifying of assertions as being true or false statements of facts, principles, or analogies and (2) drawing valid conclusions from given data.

THE IDENTIFICATION OF SOURCES OF EVIDENCE THAT CAN BE USED IN OBSERVING SUCH BEHAVIOR

As indicated in the assumptions from which this study proceeds, the hypothesis was advanced that it is possible to evaluate these aspects of scientific thinking by means of objective form, paper and pencil test. It was to the testing of this hypothesis that the second major part of the problem was devoted, namely the process of validation of the objective form, paper and pencil test.

Other sources of evidence were used as a basis of criteria against which to correlate the scores made on the scientific thinking test. These include the students' free responses in solving problems and teachers' ratings, both of which are described later in this article.

As additional evidence of the factors in operation, the following tests were administered: The Strong Vocational Interest Blank, S.R.A. Primary Mental Abilities Test by Thurstone, the Cooperative Reading Comprehension Test, Form T, and a factual information test.

The Developing of Methods of Getting the Evidence Wanted—Preliminary

The general approach to evaluation of the two aspects of scientific thinking was to present a series of problems to the students, each demanding the exercise of those abilities proposed. The criteria used for the selection of the problems were:

1. Should involve significantly important concepts.
2. Should use data that is new to the students.
3. Should use only valid and reliable sources from which to draw the data.
4. Should be pertinent and common to all students.
5. Should be within the range of comprehension of all students.
6. Should be interesting to the students.

Problems were selected, based on the major areas normally included in a first-year college physics course, namely, Mechanics, Heat, Light, and Electricity. The data contained in Part I of the test (interpretation of data) were unfamiliar to the students. The principles used in Part II (application of principles) were known to the students, but the situations in which they were required to be applied were constructed from the viewpoint of originality, to reduce student familiarity.

One source of difficulty was apparent at the outset. This type of test was probably new to the students and, therefore, might present varying degrees of difficulty in understanding the directions and methods of attack; or, what would be even less desirable, some of the students might have a partial familiarity with this type of test and others not. To reduce, if not eliminate, this variable one illustrative problem for each of the two aspects of scientific thinking was thoroughly interpreted and discussed.

Following this, groups of approximately twenty-five (25) students were presented problems requiring interpretation of data and application of principles. The interpretations and solutions to these problems were in the form of essay responses. These free responses were then made the basis for the construction of the objective form of the test.

The students' free responses to the interpretation of data were classified in terms of the kinds of relationships involved, i.e., reading and comparison of points, recognition and comparison of trends, cause and effect, value judgment, etc.

The students' free responses to the application of principles were classified as:

1. True statements of facts, principles, or analogies.
2. False statements of facts, principles or analogies.

After selection of those student responses most typical, there appeared to be certain salient points not covered. The writer supplied these from his own thinking.

THE FORM OF THE TEST DEVELOPED FOR INTERPRETATION OF DATA

At the same time the type of data to be used was selected, the form most suitable for presentation was also chosen, i.e., graphs, charts, etc.

The general form employed in constructing this part of the test was to present the data, followed by several descriptive statements based on the data. The students identified each statement as being true, probably true, insufficient evidence, probably false, or false.

Below is a sample problem and some of its test items.

INTERPRETATION OF DATA

PROBLEM 1

NAME..... DATE.....
(Last) (First)

The graph[3] on the next page is based on the amount of moisture required per day to humidify a 10,000 cubic foot house of normal construction, assuming an inside temperature of seventy (70) degrees Fahrenheit and an inside relative humidity of forty-five (45) per cent.

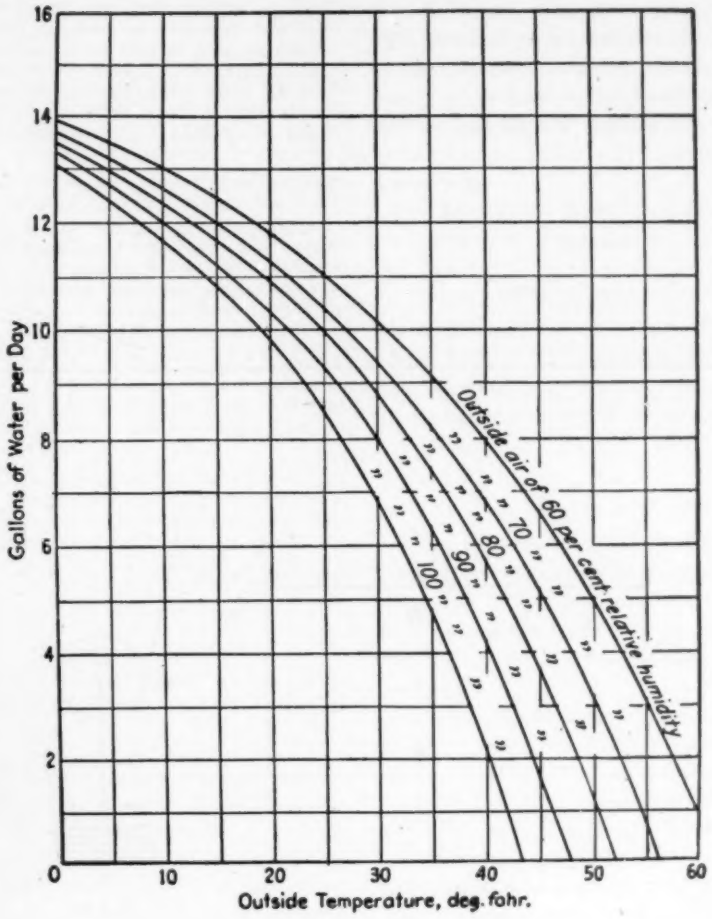
Directions: On the line before each of the statements below there are five symbols. Mark an X through the correct one.

T	True:	The information given here proves conclusively that the statement is true.
PT	Probably True:	The information given here indicates that the statement is likely to be true but is not sufficient to conclusively prove its truth.
I	Insufficient Evidence:	There is not sufficient information given here to indicate whether there is any degree of truth or falsity in the statement.
PF	Probably False:	The information given here indicates that the statement is likely to be false but is not sufficient to conclusively prove its falsity.
F	False:	The information given here proves conclusively that the statement is false.

Symbols	*Statements*
T PT I PF F 1.	When the outside relative humidity is constant and the outside temperature is dropping, the *rate* of increase of water required becomes less.
T PT I PF F 2.	When eleven (11) gallons of water are required and the outside temperature is thirty (30) degrees Fahrenheit, the outside relative humidity is approximately fifty (50) per cent.
T PT I PF F 3.	When the outside temperature is zero (0) degrees Fahrenheit and thirteen (13) gallons of water per day are supplied, frost will form on the windows.
T PT I PF F 4.	The curves of the graph lines become irregular in shape at outside temperatures between zero (0) and minus 10 (−10) degrees Fahrenheit.
T PT I PF F 5.	At any constant outside temperature between zero (0) and forty (40) degrees Fahrenheit, the lower the relative humidity of the outside air, the less water is required.

Etc.

[3] Reprinted from *Elements of Industrial Heat*, Randall, John A. and Gillon, J. Warren, by permission of John Wiley & Sons, Inc.



The Form of the Test Developed for Application of Principles

The general form employed in constructing this part of the test was first to present the problem, requiring the application of principles of physics for its solution. Since the desired evaluation was of application rather than recall, the principles involved were stated.

Next followed a series of statements concerning the problem which the students identified as acceptable or unacceptable. An acceptable statement was one that was a true statement of fact, principle, or a true analogy. An unacceptable statement was one that was a false statement of fact, principle or a false analogy. For the student who felt that he did not know the correct answer, an opportunity was given for him to so indicate. Only after a student had thought through and answered the series of statements was he asked to reach a conclusion.

It is worthy to take passing note of the use of analogies in the statements. There was some question of the advisability of their inclusion, since analogies in themselves do not offer proof. However, they

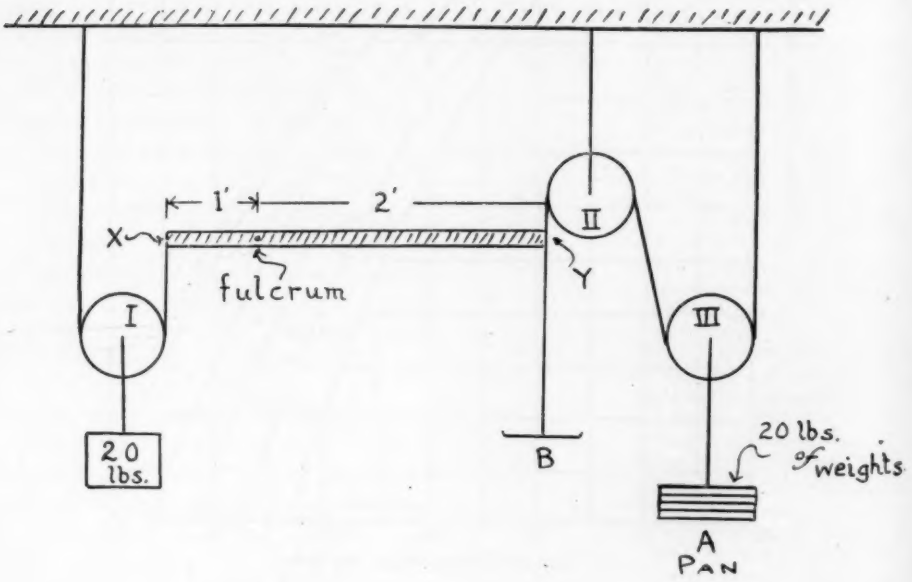
were used since reasoning, in which relations or resemblances are inferred from known relations or resemblances, does involve application of principles.

Below is a sample problem and some of its test items.

APPLICATION OF PRINCIPLES

PROBLEM 1

NAME..... DATE.....
(Last) (First)



Principles Involved:

1. The mechanical advantage of a machine = $\frac{\text{resistance}}{\text{effort}}$
2. The mechanical advantage of a lever = $\frac{\text{length of effort arm}}{\text{length of resistance arm}}$
3. Considering the weight hanging from the axis of a pulley as the resistance, the mechanical advantage of a single fixed pulley is 1, and of a single movable pulley is 2.
4. The mechanical advantage of a combination of machines is equal to the mechanical advantages of all the machines multiplied together.
5. The resultant of parallel forces acting at a point is their algebraic sum.
6. The algebraic sum of the clockwise and counter-clockwise moments of force about a fulcrum must be zero for the apparatus to be in equilibrium. (A moment of force is equal to the force times the perpendicular distance from the fulcrum to the direction of the force, and is expressed in units of pound feet.)

- - - - - - - - - - - - - - - - - - - -

A student set up the above apparatus which is *NOT* in equilibrium. He wanted to determine how many pounds of weights he must take from balance pan A and place on balance pan B, to put the apparatus in equilibrium. (Neglect the weight of the lever.)

Directions: On the line before each of the statements below there are three symbols. Mark an X through the correct one.

T	It is an acceptable statement:	It is a true statement of fact or principle, or it is a true analogy.
?	You are uncertain	
F	It is an unacceptable statement:	It is a false statement of fact or principle, or it is a false analogy.

Symbols	*Statements*
T ? F 1.	With the apparatus set up as shown above, there is a resultant upward

force at point Y of fifteen (15) pounds.

T ? F 2. Taking one (1) pound weight off of balance pan A and placing it on pan B will produce an increase in the resultant force at point Y by one and one-half (1½) pounds downward.

T ? F 3. One fixed and two movable pulleys may be combined to produce a mechanical advantage of four (4). Therefore, considering the twenty (20) pounds hanging from the axis of pulley I as the effort, the one fixed and two movable pulleys shown in the diagram have a mechanical advantage of four (4)

T ? F 4. To put the apparatus in equilibrium the rope below point Y must have five (5) pounds greater tension than the rope above.

T ? F 5. Every pound of resultant force acting downward at Y will balance two (2) pounds of the weight hanging from the axis of pulley I.

Etc.

- - - - - - - - - - - - - - - - - -

Conclusion

In the light of your answers above, place a check mark (X) before one of the following statements.

—— 1. Five (5) pounds should be taken from pan A and put in pan B.

—— 2. Ten (10) pounds should be taken from pan A and put in pan B.

—— 3. Fifteen (15) pounds should be taken from pan A and put on pan B.

—— 4. None of the above three (3) suggested conclusions are correct.

Further Steps in the Refinement of the Scientific Thinking Test

The test was submitted to twenty-nine (29) judges for criticism. These included teachers of college and high school physics and other sciences, as well as non-science personnel who offered many valuable suggestions from the viewpoint of good test construction. As a result of these criticisms the test was revised.

The test was then administered to 135 students at the New York State Agricultural and Technical Institute and the Liberal Arts College at Alfred, New York. An estimated biserial r and percentage difficulty was computed for each item.[4]

All items were discarded that did not reach an estimated biserial r of .15 or higher and were not successfully completed by fifteen (15) to ninety (90) per cent of the examinees.

Construction of the Factual Information Test

A factual information test was constructed, covering the identical topics as those used in the problems of the scientific thinking test. This test was subjected to a similar process of refinement as was the latter one.

The Testing Procedure

One hundred nine (109) freshmen at the New York State Agricultural and Technical Institute at Alfred were used as subjects. This was a separate group from any other mentioned heretofore in this study.

The problems comprising the scientific thinking test were administered in the spring term of 1948 after the factual information of the topic area in physics was presented in the usual classroom teaching. Preceding the administration of the test, an illustrative problem in interpretation of data and application of principles was used as a basis for orientation. A total of four (4) problems were used in interpretation of data and three (3) in application of principles. Only one problem was given at any one time and there was no time limit for completing the problem.

One step in the validation of the scientific thinking test was the determination of the correlation of scores made by the stu-

[4] All values as reported in this study as estimated biserial r's were computed by the method described by Flannagan, John C. "General Considerations in the Selection of Test Items and a Short Method of Estimating the Product-Moment Coefficient from Data at the Tails of the Distribution," *The Journal of Educational Psychology*, 30, (1939), 674–80.

dents' free responses in solving problems with their scores on the objective form of the test. Therefore, each problem was presented to the students for their free responses. Two days later the objective form of the test was administered to the same students.

The Vocational Interest Blank by Strong, the S.R.A. Primary Mental Abilities Test by Thurstone, the Cooperative Reading Comprehension Test, Form T, and a factual information test were administered to all the students.

The Development of Rating Scales

The following procedure was used in the developing of a rating scale to evaluate the students' free responses. Two hundred responses to one problem in each of interpretation of data and application of principles, made by one hundred students, were chosen at random. Each response was rated either as acceptable or unacceptable according to predetermined standards. An acceptable response was accredited with one (1) point and an unacceptable with zero (0).

In determining the reliability of the scales, each set of 200 responses for interpretation of data and application of principles respectively was rated separately by three judges.

TABLE I

RATING SCALE FOR FREE RESPONSES IN INTERPRETATION OF DATA AND APPLICATION OF PRINCIPLES

	Items				
	No. 1	No. 2	No. 3	No. 200	
Judge A	1	1	1	1	t_1
Judge B	0	1	1	0	t_2
Judge C	1	0	1	1	t_3
1	1_1	1_2	1_3	1_{200}	$\Sigma t = \Sigma 1$

The reliability of the rating scale was determined by Hoyt's method. With the reliability of the rating scale established (see Presentation and Interpretation of Results), the writer proceeded to rate 4,488 students' free responses.

In developing a rating scale for the teachers' estimate a different procedure was used. First, must be mentioned the unique opportunity afforded at the Technical Institute for rating students on the abilities involved in interpreting data and applying principles. In the laboratories and shops the students were required to carry on those activities that were later to be their means of livelihood. For example, students in radio were given a radio set with certain predetermined errors that accounted for its non-function. They were required to detect and repair the set, utilizing any data or principles they wished. Students in the other courses of refrigeration and air conditioning, power, and construction were presented with similar practical problems pertinent to their field requiring interpretation of data and application of principles. Thus, the situation was most favorable from the standpoint of requiring the exercise of those abilities that were to be rated and also because of the great incentive afforded by the practicality of the problems.

The four cooperating teachers rated the various groups of students, based on observation from September 1947 to April 1948. It was found from actual trial that the rating of students separately for the abilities to interpret data and to apply principles was unworkable. The tasks performed by the students were such as to require the exercise of both of these abilities interdependently. To accurately determine and rate the extent to which each ability independently operated in the success or failure proved unfeasible. Therefore, one general rating was made on a seven (7) level basis for these two abilities.

Each task performed by the students in the shops and laboratories was from four (4) to eight (8) hours duration. These tasks were rated by the instructors on the

seven (7) level basis for the ability to interpret data and apply principles. One final and overall rating on the same basis was made by each instructor for the students under him.

No one instructor rated all students, but each student was rated by two instructors. These ratings from each teacher were converted into T′-scores and an average computed for each student.[5]

Methods of Scoring the Scientific Thinking Test

The method of scoring the application of principles was to credit one (1) point for each correct response and assign an arbitrary five (5) additional points for a correct conclusion. Less than one-half (½) of one (1) per cent of the responses made were "?". Since a special rating for this percentage would not significantly change the correlations, they were scored as incorrect.

The method of scoring the interpretation of data was more difficult. Four methods were used, to determine which yielded a higher coefficient of reliability and also which showed the highest correlation with the teachers' estimates. This latter criterion was used since it constituted the most valuable basis of determining validity.

Without going into the details of reasoning behind their selection, the four methods are described briefly below:

Method A

One (1) point was accredited for each response that corresponded with the key.

[5] All T′-scores in this study were computed by:

$$\text{T′-score} = \frac{X - M}{\sigma} \times 10 + 50, \text{ where}$$

X = raw score
M = mean
σ = standard deviation of the distribution

The T′-scores differ from McCall's T-scores in that the latter are based on a normal curve while the distribution of scores in this study do not exactly fit the normal curve.

Method B

One (1) point was accredited for each response that corresponded with the key, and also one (1) point for an answer of "Insufficient Evidence" when the key called for "Probably True" or "Probably False."

Method C

One (1) point was accredited for each response that corresponded with the key, and also one (1) point for an answer of "Probably True" or "Probably False" when the key called for "Insufficient Evidence."

Method D

Weighted scores were given as indicated in Table II.

TABLE II

WEIGHTED SCORES METHOD OF RATING INTERPRETATION OF DATA

		Key				
		T	PT	I	PF	F
Student Responses	T	4	3	2	1	0
	PT	3	4	3	2	1
	I	2	3	4	3	2
	PF	1	2	3	4	3
	F	0	1	2	3	4

PRESENTATION AND INTERPRETATION OF RESULTS

The presentation and interpretation of the results fall into two classifications. One, the results obtained by procedures followed in the test construction and two, statistical treatment of the test scores.

Evaluation of Results Obtained by Procedures Followed in the Test Construction

It is felt that since the procedures followed in the test construction as described above were those generally accepted by experts in this field, they did contribute to the validity and reliability of the test.

One of the premises was that this test should provide an opportunity for the student to demonstrate the specific behaviors defined in the objectives. That this oppor-

tunity was provided in the interpretation of data may be seen by examining the following table used in the interpreting of the responses.

TABLE III

INTERPRETATION OF STUDENTS' RESPONSES IN TERMS OF BEHAVIORS

		Key				
		T	PT	I	PF	F
Students' Responses	T	A *	BD	BD	E	E
	PT	C	A	BD	E	E
	I	C	C	A	C	C
	PF	E	E	BD	A	C
	F	E	E	BD	BD	A

* A = accurate
C = too cautious
BD = beyond the data
E = error

In the problems involving application of principles, an opportunity was provided for demonstrating the specific behaviors, by selecting from the objective form of the test, those student free responses most frequently expressed that were both correct and incorrect statements of facts, principles, or analogies and those conclusions both acceptable and unacceptable.

EVALUATION OF RESULTS OBTAINED BY STATISTICAL TREATMENT OF THE SCORES

Rating of Test Items for Estimated Biserial r and Percentage Difficulty

Table IV shows the ranges and means of the estimated biserial r's and percentages of difficulty (the percentages of students who successfully completed the item) for each problem used in the scientific thinking test.

TABLE IV

RANGES AND MEANS OF ESTIMATED BISERIAL r's AND PERCENTAGES OF DIFFICULTY OF ITEMS

	Estimated Biserial r		Percentage of Difficulty	
	Range	Mean	Range	Mean
Interpretation of Data				
Problem 1	21–82	53	37–90	59
Problem 2	22–82	46	37–95	69
Problem 3	21–71	45	27–92	63
Problem 4	21–72	44	34–87	68
Application of Principles				
Problem 1	23–70	43	24–92	65
Problem 2	24–75	48	41–91	64
Problem 3	29–67	47	53–91	72

Results of Scoring Interpretation of Data by Four (4) Methods

Table V shows the reliabilities of scores on the interpretation of data and the correlation between the scores on interpretation of data and the teachers' estimate.

There is no statistically significant difference between any two of the four methods in respect to either reliability or correlation with teachers' estimates. However, method A was selected since it did have higher r's and also because it was the simplest method of scoring.

It may be well to note that, whereas scoring responses on a strictly right or wrong basis may be most suitable for research purposes, the method of weighted

TABLE V

RESULTS OF SCORING INTERPRETATION OF DATA BY FOUR (4) METHODS

	Methods			
	A	B	C	D
Reliabilities (Split-Halves)	.83 * **	.78 ± .04	.74 ± .04	.82
Correlation with Teachers' Estimates	.56 ± .07	.40 ± .08	.46 ± .08	.47 ± .08

* All reliabilities for tests reported in this study were computed by the split-halves method and corrected by the Spearman-Brown formula.

** Although it is possible to compute standard errors for r's of .80 or over, none are reported in this study since such r's are not normally distributed.

scores has certain advantages for instructional purposes. From a student morale point of view, it may be wise to give greater credit to a student who, for example, answered "Probably True" to a "True" statement than to one who responded "False." Further, the method of weighted scores is more in keeping with a finer analysis of students' responses as suggested in Table III.

Distribution of Scores on the Scientific Thinking Test

Table VI shows the summary of data on the scientific thinking test.

any significant difference. The resulting t-ratios were

Total Test	.835
Interpretation of Data	.129
Application of Principles	1.06

None of these t-ratios are significant.

Interest in scientific matters, as measured by the Strong Vocational Interest Blank, apparently did not significantly influence scores on the scientific thinking test.

The Factors of Reading as Related to the Scientific Thinking Test

Table VII shows the correlations of scores on the scientific thinking test with scores on general reading ability.

TABLE VI

SUMMARY OF DATA ON SCIENTIFIC THINKING TEST* **

	N	Range	Mean	S.D.	r reliability
TOTAL SCIENTIFIC THINKIG TEST	109	22–70	50.0 ± .94	9.8 ± .67	.96
Interpretation of Data					
Total	109	37–73	51.9 ± .85	8.78 ± .60	.83
Problem 1	109	5–19	12.5 ± .34	3.56 ± .24	.72 ± .05
Problem 2	109	6–19	13.3 ± .25	2.62 ± .18	.71 ± .05
Problem 3	109	5–19	12.9 ± .28	2.94 ± .20	.51 ± .07
Problem 4	109	7–19	13.5 ± .25	2.56 ± .18	.51 ± .07
Application of Principles					
Total	109	22–58	39.8 ± .70	7.28 ± .50	.88
Problem 1	109	5–20	14.0 ± .28	2.86 ± .20	.72 ± .05
Problem 2	109	5–19	9.87 ± .29	3.06 ± .21	.62 ± .06
Problem 3	109	7–23	15.92 ± .36	3.69 ± .25	.71 ± .05

* Students' scores on interpretation of data and application of principles were converted into T′-scores. These T′-scores were then averaged to obtain a student's score on the total scientific thinking test.

** Range, mean, standard deviation, and r for the total scientific thinking test are in terms of T′-scores. All others are in raw scores.

The Factor of Interest as Related to the Scientific Thinking Test

Strong's Vocational Interest Blank was administered and scored for key two (2) (scientific interest). Twenty-eight (28) students scored low (C, C$^-$, and B$^-$) and thirty-nine (39) scored high (A). Of this latter group, twenty-eight (28) were chosen at random. The mean of the scores made by these two groups on the scientific thinking test were compared to determine

There is no significant difference between any two r's shown in Table VII.

A correlation of .38 between scores on the scientific thinking test and reading ability test shows a low positive correlation. It may be surprising to note the relatively low correlations between the total and subscores on the reading test and the scores on the scientific thinking test. One fact to be considered is that there was no time limit placed on completing the problems

TABLE VII

CORRELATIONS OF SCORES ON THE SCIENTIFIC THINKING TEST WITH SCORES ON GENERAL READING ABILITY

	Scientific Thinking Test		
READING TEST	Total Test	Interpretation of Data	Application of Principles
Total Test	.38 ± .08	.36 ± .08	.29 ± .09
Vocabulary	.22 ± .09	.23 ± .09	.21 ± .09
Speed	.32 ± .09	.38 ± .08	.31 ± .09
Comprehension	.32 ± .09	.31 ± .09	.22 ± .09

of the scientific thinking test while there was a time limit for the reading test.

These correlations would suggest that there are factors other than reading ability that account, to a greater extent, for the differentiation in scores on the scientific thinking test.

Table VIII shows the correlations of scores on the scientific thinking test with scores on the factors of intelligence.

The correlation of .23 between scores on the application of principles and reasoning is significantly higher than that of −.08 between the scores on application of principles and number. None of the other scores on factors of intelligence correlates significantly different with the total test, interpretation of data, or application of principles scores.

The correlation between scores on the factors of intelligence and the scientific thinking test are either slight or low. One

TABLE VIII

CORRELATIONS OF SCORES ON THE SCIENTIFIC THINKING TEST WITH SCORES ON FACTORS IN INTELLIGENCE

	Scientific Thinking Test		
INTELLIGENCE TEST	Total Test	Interpretation of Data	Application of Principles
Total Test	.19 ± .09	.24 ± .09	.09 ± .10
Verbal Meaning	.22 ± .09	.23 ± .09	.11 ± .10
Space	.14 ± .09	.19 ± .09	.12 ± .10
Reasoning	.24 ± .09	.25 ± .09	.23 ± .09
Number	.01 ± .10	.14 ± .09	−.08 ± .10
Word Fluency	.06 ± .10	.04 ± .10	.07 ± .10

TABLE IX

SUMMARY OF DATA ON THE FACTUAL INFORMATION TEST

N	Range	Mean	S.D.	r(reliability)
109	33–62	47.2 ± .61	6.33	.84

TABLE X

CORRELATION OF SCORES ON THE SCIENTICIC THINKING TEST WITH SCORES ON THE FACTUAL INFORMATION TEST

	Scientific Thinking Test		
	Total Test	Interpretation of Data	Application of Principles
Factual Information Test	.62 ± .06	.56 ± .07	.52 ± .07

point is to be remembered, that there was no time limit imposed on completing the problems in the scientific thinking test while time limits were used in Thurstone's Primary Mental Abilities test. However, these correlations lend support to the hypothesis that whatever aspects are being measured by the scientific thinking test, they are different from those of intelligence, as measured by Thurstone's Primary Mental Abilities.

The Factor of Knowledge of Factual Information as Related to the Scientific Thinking Test

Table IX shows the summary of data on the factual information test used in this study.

Table X shows the correlation of scores on the scientific thinking test with scores on the factual information test.

There is no statistically significant difference between any of the two correlations.

Whereas, the coefficient of correlation (r) between scores on the total scientific thinking test and the factual information test was .62, the coefficient of alienation (k) was .78.[7] Therefore, the degree of relationship is *less* than the degree of *lack* of relationship.

Also, the coefficient of determination may be computed by squaring r. The coefficient multiplied by 100 gives the variance in Y that is associated with the variance in X. For these scores with an r of .62, the percentage of variance in Y that is associated with X is 38. The percentage of the variance in Y *not* associated with variance in X is given by $100k^2$, and is the coefficient of non-determination. For these scores, the coefficient of non-determination is 62.

Based on the above interpretations it may be concluded that, even though students may be high in their knowledge of factual information, this is no guarantee that they can use this knowledge for the solution of problems, such as were used in this test.

Relationship Between the Scientific Thinking Test and the Teachers' Estimates

Table XI shows the correlations of scores on the scientific thinking test and the teachers' estimates.

There is no statistical difference between any two of the correlations.

The moderate to high positive correlations shows a substantial to marked relationship between the scores on the scientific thinking test and the teachers' estimates. It was one of the hypotheses of this study that the teachers' estimates could be a valid criteria against which to judge the scientific thinking test. Considerable effort and care were used in guiding this phase of rating the students' behavior in the shops and laboratories. The magnitude of the correlations indicates that whatever aspects were being rated by the teachers were also being measured to a substantial degree by the scientific thinking test.

Relationship Between Scores on the Scientific Thinking Test and the Students' Essay Responses

To rate the students' free responses, a rating scale was developed as described

[7] $k = \sqrt{1 - r^2}$

TABLE XI

CORRELATIONS BETWEEN SCORES ON THE SCIENTIFIC THINKING TEST AND TEACHERS' ESTIMATES

	Scientific Thinking Test		
	Total Test	Interpretation of Data	Application of Principles
Teachers' Estimates	.71 ± .05	.56 ± .07	.68 ± .05

above. The coefficient of reliability was determined by Hoyt's method and was found to be .90 for the scale on interpretation of data and .97 for the scale on application of principles.

The correlation between scores on the objective form and the students' essay responses in interpretation of data was .66 ± .06. The correlation between scores on the objective form and the students' essay responses in application of principles was .69 ± .05. There is no statistical difference between these correlations.

Of course, the correlation represents one between two variables. Since the correlation coefficient is to be used as a measure of validity (the degree to which the ability to make original interpretations of data and application of principles can be predicted from a score on scientific thinking test), it is not legitimate to correct for attenuation due to the unreliability of the latter test. If this test is to be used for predictive purposes, the fact must be recognized that it is not perfect. However, it is defensible to correct for the reliability of the criterion.

The reliability of the students' essay responses on the interpretation of data was .68 ± .05. Using this reliability coefficient, the correlation between scores on interpretation of data and the students' essay responses, corrected for attenuation, was .80. Likewise, the reliability of students' essay responses in application was .71 ± .05. The correlation between scores on the application of principles and the students' essay responses, corrected for attenuation, was .82. These correlation coefficients are sufficiently high to warrant group predictions and are of some value for individual predictions.

Relationship Between the Measured Aspects of Scientific Thinking

The intercorrelation of scores between the interpretation of data and application of principles was .48 ± .08. This indicates the aspects are not identical but do have a moderate positive correlation.

The correlation coefficient of .48 also means a coefficient of determination of 23, i.e., the percentage of variance in Y that is associated with X is 23. The magnitude of this coefficient of determination is sufficiently low to justify the appraisal of each of these abilities separately.

CONCLUSIONS

1. The steps followed in the test construction did contribute to its validity.

2. Since great care was taken to rate students in the ability to interpret data and apply principles in actual performance in the shops and laboratories, the correlation of .71 between scores on the teachers' estimates and the scientific thinking test indicates that the aspects being measured by the scientific thinking test were to a substantial degree also interpretation of data and application of principles.

3. The correlations of scores between the students' free responses and the objective form of the scientific thinking test are sufficiently high to warrant group predictions and are of some value for individual predictions.

4. The correlations between scores of the factors of reading and the scientific thinking test suggest that there are factors other than reading ability that account, to a greater extent, for the differentiation in scores on the scientific thinking test.

5. Whatever aspects were being measured by the scientific thinking test, they were different from those of intelligence as measured by Thurstone's Primary Mental Abilities.

6. A correlation coefficient of .62 between scores on the scientific thinking test and factual information represents a coefficient of determination of .38, i.e., the percentage of variance in Y that is associated with X is 38. Thus, even though students may be high in their knowledge of factual information, this is no guarantee they can

use this knowledge for the solution of problems such as used in the scientific thinking test.

7. The correlation of .48 between scores on interpretation of data and application of principles is sufficiently low to justify the appraisal of each of these abilities separately.

Implications for Further Study

Problems suggested for further study are:

1. Additional research on identifying aspects of scientific thinking that are independent, and an analysis of these in terms of behaviors.

2. Development of methods by which these identified abilities may be evaluated. The methods are, of course, not limited to paper and pencil tests but nevertheless should be developed from the viewpoint of becoming usable procedures in the hands of average classroom teachers.

3. Determination of what teaching methods are most conducive to the development of scientific thinking. If this study has shown the test used is a valid measure of the abilities to interpret data and apply principles, then it may be used as a criterion against which to judge certain instructional practices. However, there is great need of additional instruments and procedures at different grade levels to properly evaluate various teaching methods in respect to the development of scientific thinking.

A STUDY OF SCIENCE FOR GENERAL EDUCATION AT THE COLLEGE LEVEL *

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This study of college science courses designed for general education was started in the spring of 1948. It is a sequel to a *Conference on Science in General Education* held at Princeton, New Jersey, in December of 1947. It is also an extension of the study of the NARST Research Committee on Junior College Science which was reported at the 1948 annual meeting.[1]

The study has been sponsored by, and has had the active support of, the Cooperative Committee on the Teaching of Science and Mathematics of the American Association for the Advancement of Science.

* This paper is adapted from a part of a dissertation to be submitted in meeting the requirements for the Ph.D. degree at Northwestern University, Evanston, Illinois.

[1] W. C. Van Deventer, "Report of the Research Committee on Junior College Science," *Science Education*, 32:188–193, April, 1948.

PURPOSE OF THE STUDY

The purpose of this study is to determine the status, trends, objectives, content, procedures, problems, and values for general education of college-level science courses which are especially designed for students who do not plan to specialize in science. Many of these courses have been called by such names as survey, generalized, orientation, integrated, or foundation courses. All of the above-named courses have in common the inclusion of more than one specialized field of science. Also included in this study are single-subject courses that have been modified to meet the needs of general education. All types being studied will herein be referred to as *general education science courses.*

PROCEDURES USED

In order to secure information on the types and prevalence of courses an inquiry

was sent to the administrators in 967 four-year colleges, universities, and teachers' colleges in the United States. Replies were received from 660 schools. In addition a survey of 600 college catalogs gave information concerning 60 more schools.

To secure detailed information about the specific courses designed for general education a seven-page questionnaire was sent to a selected group of 300 science teachers. Suitable course descriptions were received for 150 courses distributed among 103 schools of all sizes. Of this group 28 are teachers' colleges.

The data supplied on the questionnaires have been supplemented in a number of ways. For many courses either outlines, syllabi, or textbooks are available for study. There are published articles describing a number of the courses.

By personal visits I have investigated the courses in 15 schools. Teachers and administrators have been interviewed and, where possible, classes have been attended.

To secure a student appraisal of general education science courses a student opinionnaire has been submitted to students in a selected group of courses.

SCOPE OF THE STUDY

The large amount of data available makes it necessary to limit this report to certain phases of the study. I will report at this time on the prevalence of general education science courses, the types of courses, the science requirements in the colleges, and some of the trends that seem to be developing.

Included in the study, but omitted entirely from this report, is information concerning course objectives and subject-matter content, the teaching personnel, procedures of instruction, and evaluation of the courses.

PREVALENCE OF COURSES

Data concerning the general education programs in science are available from 720 schools. Of these schools 293 (41 per cent) report either that they have no general education courses in science or report the usual introductory courses as meeting the schools' science requirements.

The remaining 59 per cent or 437 schools, 118 of which are teachers' colleges, offer various types of courses for general education. The kinds of science programs designed for general education are:

In 221 schools, companion courses, one in the biological sciences and one in the physical sciences.

In 81 schools, a general course over both large areas of science.

In 58 schools, only a course in the biological sciences.

In 42 schools, only a course in the physical sciences.

In 63 schools, specially designed single-subject courses.

The above list includes 28 schools that offer general education courses in more than one of the categories.

If we include the general courses with the companion courses in the biological and physical sciences, we find that 302 out of 720 schools (42 per cent) offer general education science in both of the major areas.

From one to six single-subject courses (botany, physics, etc.) are found in any individual school.

The previously-mentioned classifications of science courses are not distributed evenly through the teachers' colleges and the colleges and universities of various enrollments. General education courses in science are much more prevalent in teachers' colleges than in other schools. Of the teachers' colleges reporting, 81 per cent offer courses. Courses are least common in schools of 2,500 to 5,000 students and in the group with less than 500 students. Slightly less than one-half of the schools in these groups offer courses. From 57 to 62 per cent of the schools of other size classifications have courses.

In the teachers' colleges the courses are predominantly a combination of physical

and biological science or else of the general type. The combination programs are distributed evenly through all sizes of the colleges and universities, but there is a definite scarcity of general courses in the larger schools.

Special single-subject courses are not as common as the combination programs, except in schools over 10,000 where they equal them in number. The single-subject courses find more favor in the larger schools.

The data of this study indicate that general education courses in science are now much more prevalent than at any previous time. Earlier studies have revealed these courses in not more than half of the four-year colleges of the United States.

TYPES OF COURSES

The 150 general education science courses included in this study will be classified in two ways. The first is by subject-matter content and the second is by method of approach in presenting the content.

1. *Classification by Content.* The 150 courses are divided into the following six categories on the basis of subject-matter content.

a. The general course (17 in number). The general course has often been called a survey course. Its subject-matter is derived from the biological and physical sciences usually divided equally in time allotment. Earth science often contributes some material which is generally offered under the heading of physical science. Nearly all courses of this group are one year in length although a few are of one semester or two quarters duration.

b. The biological science course of one semester (17 courses). This type of course is essentially the same as the biology half of the general course, and usually it is paired with a companion physical science course. Those that are here included as separate courses are offered by a different teacher or department than the physical science and thus are reported on the questionnaires as distinct courses.

c. The biological science course of one year (35 courses). The course in biology or biological science that extends through one year is the most common type of general education science course offered in the colleges and universities.

d. The physical science course of one semester (12 courses). This course is usually a companion to a semester of biology but is offered by a separate staff.

e. The physical science course of one year (39 courses). This course includes materials from the various physical sciences. Often the subject matter is drawn largely from chemistry and physics and occasionally it is taken mostly from astronomy and geology. There is considerable variation in the content of this type.

f. The single-subject course (28 courses). Single-subject courses that are designed especially for general students rather than science majors are becoming common. They may be found in all branches of science but more commonly in chemistry and physics than in any other. A few courses in the history of science are included in this category.

The length of the single-subject course may be one quarter, one semester, or one year. The one-semester courses are the most common. In some schools two of these courses form a year sequence, e.g., a combination of chemistry-physics, astronomy-geology, or botany-zoology.

It is quite possible that the method of presentation or approach to the subject matter is of more importance than the actual content. Courses will now be considered from this standpoint.

2. *Classification by Teaching Approach.* The following statement was included in the questionnaire for course descriptions:

> Please check the item below which best describes the approach which you use.
>
> A subject-matter survey.
>
> An intensive study of selected units.

A study of certain selected problems.
Based on the historical development of a science or sciences.

Please state other basis of approach.

The subject-matter survey approach is the most commonly used method of teaching. It is reported as the only method in 42 courses. The study of selected units is used in 31 courses and ranks second.

In consideration of the current emphasis upon problem-solving and the use of the scientific method, it is surprising that only 20 of 150 courses show the use of selected problems as the basic approach, with 13 more using this method in combination with another. The historical development of science is used in 11 courses.

In the 30 courses reporting a combination of procedures, the survey was used in 20, the historical approach in 18, the study of selected units in 15, and the study of selected problems in 13.

The word "survey" is objectionable to many teachers. In discussing their courses they hasten to say they are not survey courses. We frequently read that survey courses are being abandoned. They are criticized from many standpoints.

Therefore it seems significant that the teachers of 62 out of 150 courses have listed them in whole or in part as subject-matter surveys. One would expect all of the general courses to be surveys and the single-subject courses to be otherwise, but such is not the case. Only five of the 18 general courses are listed as surveys while nine of 28 single-subject courses are so classified. These nine are all one-semester courses. In many schools these single-subject courses have been organized for general education in order to avoid the real or imagined evils of the so-called survey courses.

It is appropriate to consider here the meaning of the term "survey." The *Dictionary of Education* gives the following definition:

Course, survey: a course designed to give a general view of an area of study, often as a means of introducing an unfamiliar field to pupils or students before undertaking specialized work or providing them with broad, general concepts about an area in which they may or may not plan to specialize.

When used in the above sense, the term "survey" is applicable to all introductory courses in science, whether they be designed for science majors or for general students. This viewpoint is supported by Dunn in *Science in General Education.*

All introductory courses in science are of the "survey" or "general" type in a sense, since they bring together material from many more highly specialized areas. Thus a science major takes "general chemistry" or "general zoology" as beginning courses.[2]

There is a different meaning frequently given to the word "survey." It is expressed by Havighurst as follows:

A survey course is any course intended for college freshmen or sophomores primarily as part of their general education which draws its subject matter from two or more of the ordinary college departments.[3]

This viewpoint has been all too prevalent among teachers. It has tended to stigmatize the words "survey," for many scientists have been strongly opposed to courses which included more than one science. Some subject-matter specialists have severely criticized one of their number who would be unfaithful enough to broaden a course to take in a rival area. They have looked upon teachers in other areas of science as incompetent if they ventured to include two or more subjects in their courses. The feeling has been prevalent that no one person is capable of teaching in two or more fields of science.

Another source of opposition to the so-called survey courses, and in fact all general education science courses, has been the real or imagined danger of attracting students away from the introductory science courses.

[2] McGrath, E. J., Editor, *Science in General Education*, Dubuque, Iowa: Wm. C. Brown Co., 1948, p. 297.

[3] R. J. Havighurst, "Survey Courses in the Natural Sciences," *American Physics Teacher*, 3:97, September, 1935.

It is high time that the situation concerning the interpretation of the word "survey" be clarified. Let us look upon "survey" as a method of approach as appropriate for introductory science courses as it is for those covering broader fields. We should not let "survey course" be considered as a synonym for "general education course."

I suggest that science courses be classified according to their ultimate ends; that is, they should be divided into those that are designed as an introduction to a science and those planned as general education in science. The term "general education science course" is much more meaningful than the expression "survey course."

In the responses to the questionnaires there were several other interesting approaches described. They indicate that much experimental work is being done to discover better ways of presenting science to non-science students. There is not time to discuss these methods here.

The common methods of approach used in general education science courses are, in order of frequency, the subject-matter survey, the study of selected units, the study of selected problems, and the historical treatment of subject matter.

SCIENCE REQUIREMENTS

How much science is required of general or liberal arts students? Definite information is available from 118 schools. Nearly one-half, 55 schools, require one year and three require less. Twelve assign one and one-half years of science. Forty-four require two years; three require more.

These figures indicate only the general trend. It must be noted that there are numerous exceptions to the requirements in most schools. In fact, the whole subject of course requirements for college students is in a state of utter confusion. It is sometimes quite easy for students to avoid some of the required courses. In some liberal arts colleges, relatively few students take the general education science courses.

In a few schools students may be exempted from science courses by passing examinations or on the basis of courses taken in high school. Most teachers recognize the problem of coordinating college science with that taken in high school. It deserves more attention and careful study.

What kinds of science courses are required? There is wide variation in practice but certain requirements are more common than others.

Among 33 teachers' colleges for which information is available there are 14 schools that require a one-year general course of all students except science majors. Eight other schools require a two-year program in the biological and physical sciences. The remaining schools have various other requirements.

Information is available from 97 liberal arts colleges. The most common practice is to require work in both the biological and physical sciences. A two-year program in these areas is required of liberal arts students in 20 schools, while in 28 schools students may either elect courses in the two areas or choose from introductory science courses. Ten schools offer a choice among a varying number of special single-subject courses. Nine schools require a general course. Thirty additional schools have a variety of other requirements.

CHANGES AND TRENDS

Why are general education science courses not offered in many schools? In general, either there is direct opposition, the need is not recognized, or the school is making plans for curriculum revision.

Twenty-nine schools reported that courses were being planned for 1948–1949. Twelve others were making plans for courses at some future time. Reports from administrators in 46 additional schools indicated that they would like to have such courses but do not for various reasons. Chief among these reasons are opposition

of the present science staff and lack of suitable teachers for general education courses.

A common opinion among teachers and administrators is that the regular introductory science courses are wholly adequate to meet the needs of general education. It is natural that many are satisfied with the *status quo*. There are always some who vigorously resist change of any kind.

On the other hand the present prevalence of general education science courses is sufficient evidence that a large body of educators has recognized the need for a change.

A number of such science courses have been started and then dropped. Information from cards returned by 473 schools indicates that courses have been abandoned in 19 of them. More detailed information on questionnaires returned by administrators from 185 additional schools shows that at least 23 of these schools have dropped courses in the last 20 years. This has occurred in 12 of the 23 schools since 1940.

It should be noted that in several instances the courses were replaced by other types of general education science courses. The courses that were dropped had lasted from one to 16 years with an average life of seven years.

The type of course most frequently abandoned was the physical science course. Twelve schools dropped this type and five of these schools also dropped a companion course in biological science. Five other schools abandoned a general science course.

The most common reasons for dropping courses were that they were too superficial or that the subject matter could not be properly integrated. These faults may be attributed to the teachers offering the courses. Other courses were dropped because of insufficient staff, lack of teacher interest, lack of student interest, changes in teaching personnel, or as an economy measure.

Are new courses being developed at a more rapid rate than the abandonment of unsatisfactory courses? The answer is "yes". Let us examine the dates of origin of the 150 courses from 103 schools concerning which we have specific data.

Twenty-three of the 150 courses were developed in 1947, the year of greatest activity. In the four post-war years 61 courses (41 per cent of the total) were organized. Only 14 courses originated in the four war years of 1941 through 1944. Twenty-three courses originated in the four years prior to the war. In the ten years since 1938 a total of 89 courses (59 per cent) were developed. Thus a majority may be considered as relatively new in the curriculum.

It is significant that only three of 17 general courses have arisen in the last four years, while 16 of a total of 28 single-subject courses have appeared.* Approximately one-third of both the physical science and biological science courses are post-war developments. The pre-war development of these courses was approximately parallel.

It appears that new courses are being developed at a much greater rate than courses are being abandoned. The science courses designed for general education are becoming more prevalent. Integrated courses in each of the two large areas of science are leading the way. The single-subject courses are rapidly increasing. Very few of the general courses, those originally called survey courses, are being developed.

CHANGES IN COURSES

Few teachers feel that they have arrived at the best possible course in science for general education. Most teachers reported recent changes or those planned for the near future. The changes are largely variations in subject-matter content and in teaching procedures. Others involve the method of approach, integration of the subject matter, and length of course. In a few

* It should be noted that the 28 single-subject courses represent only 17 schools. The 16 of recent origin are found in 11 schools.

courses there is an increased emphasis upon training students in the techniques of problem-solving.

Most changes are made on the trial and error basis. The significant point is that teachers are trying to improve their courses. Out of their efforts undoubtedly will come real improvements in all phases of science teaching.

SUMMARY

Let us summarize the findings reported in this paper.

1. Over half of the four-year institutions of higher learning in the United States offer general education science courses.

2. The most common type of program consists of companion courses in the physical and biological sciences.

3. There has been a recent development of special single-subject courses.

4. General education science courses increased in prevalence in the post-war years.

5. The common types of teaching approach are, in order of prevalence, the subject-matter survey, the study of selected units, the study of selected problems, and the historical approach.

6. About half of the colleges require one year of science of the general student. The other half require more than one year with the two-year requirement being the most common.

7. The most common requirement is work in both the physical and biological sciences.

8. Many general education science courses are undergoing changes and improvements.

A DIRECT APPROACH TO THE TEACHING OF THE SCIENTIFIC METHOD

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THIS paper is but a preliminary report on a cooperative research project being conducted at the present time by some fifteen teachers with more than a thousand students, to see if certain elements of the scientific method can be taught directly by the use of a specific type of instrument in connection with selected demonstrations. Back of this project are the assumptions that the scientific method is an effective way of solving problems, and that the best way to go about teaching something is to organize to teach it directly.

During the summer of 1948 a series of instruments were developed for use in general science, biology, physics, and chemistry classes. The general science instruments consist of a composite from the others. Only five instruments were completed in biology, but there were ten instruments for use in each of the other areas. The general science instruments are entitled:

1. How does water affect a hot fat fire?
2. What happens when a can of steam is sealed and allowed to cool?
3. How is the face warmed with tin foil?
4. What gases are used and produced as seeds germinate?
5. How does the Cartesian diver work?
6. How does a fine wire screen affect an alcohol flame?
7. How does the iris respond to light?
8. How does a mercury barometer work?
9. How do plants respond to light?
10. How does hot potassium chlorate affect charcoal?

The biology instruments are entitled:

1. What effect does saliva have on starch?
4. What gases are used and produced as seeds germinate?
5. What heat changes, if any occur during the germination of seeds?
7. How does the iris respond to light?
9. How do plants respond to light?

The physics instruments are entitled:

1. How can the earth's magnetism be used in making a magnet?
2. What happens when a can of steam is sealed and allowed to cool?
3. How is the face warmed with tin foil?
4. How is a ball held up in a stream of air?
5. How does the Cartesian diver work?
6. How do gases pass through a porous cup?
7. How does a balloon act under reduced pressure?
8. How does a mercury barometer work?
9. How is an object buoyed up in water?
10. What is the effect of a change in pressure on the boiling point of water?

The chemistry instruments are entitled:

1. How does water affect a hot fat fire?
2. What makes the ammonia fountain work?
3. What is the reaction of potassium and water?
4. What is the effect of sulfuric acid on sugar?
5. What happens when paper coated with white phosphorus is exposed to air?
6. How does a fine wire screen affect an alcohol flame?
7. What is the effect of sulphuric acid on a mixture of potassium chlorate and sugar?
8. What happens when finely divided lead is exposed to the air?
9. How does carbonic acid affect limestone?
10. How does hot potassium chlorate affect charcoal?

In connection with each of the tests a three-page direction sheet was written. All of the direction sheets and all of the tests were organized according to the same pattern. The tests were all written so that the answers could be checked on a separate score sheet which can be scored by machine. To arrange the test items in this fashion meant that many of them had to be stated negatively as you can see by the attached sample. The answers from all ten of the tests in each set can be checked on a single score sheet so there is but one set of answers from each student participating in the project. The particular sample test which is included in this paper is chosen because it is less familiar to most of you and should therefore be more interesting. It is the eighth test in the chemistry group.

Step one of the direction sheet is planned to orient the class so that they will be receptive to the demonstration that is to follow. Step two consists of detailed directions for performing a demonstration. Detailed drawings are included to aid the teacher in the particular techniques of the demonstration. Step three instructs the demonstrator to relate what happened in the demonstration to the past experiences of the student. Step four instructs the demonstrator to pass out the tests and score sheets and to have the students answer the questions. Step five asks that the score sheets be collected. Step six instructs the demonstrator to tell the students the correct answers. This terminates the experience for the control groups, but additional suggestions are given for use with the experimental groups. Step seven instructs the demonstrator to use the instrument in every way possible to teach the scientific method. He is to promote discussion of the test items. It is pointed out that the first test item is concerned with what happened in the demonstration, the second test item includes one statement which explicitely describes the demonstration. The third test item consists of five hypotheses to account for what happened. Test items four to eight consist of additional facts which are to be used in checking each hypothesis. Test item nine is concerned with the assumptions that are made in drawing the correct conclusion; item ten, with new questions that arise in connection with the demonstration; item eleven with assumptions that underly an application of the conclusion and item 12 with a direct application of the conclusion. Perhaps these statements will be clear if considered in connection with instrument eight entitled, What happens when finely divided lead is exposed to air?

Directions for Administering Instrument Number 8 Entitled, What Happens when Finely Divided Lead is Exposed to Air?

I. Orientation.

By Discussion and by questions arouse interest in an experiment on the oxidation of lead. Use care not to tell the answers to the questions in the test.

1. Show a small block of wood. Ask which would burn or oxidize the easier, this block or the same amount of wood reduced to fine sawdust. Suggest that oxidation is after all a surface effect.

2. Show a small amount of sheet lead. Scrape or sandpaper off a portion of the oxide formation and call attention to the difference in color between the black lead oxide and the unoxidized lead. Call attention to the fact that even though lead is a readily active element, the quickly formed lead oxide forms a protective film over the substance.

II. Demonstrate what happens when finely divided lead is exposed to air in the following steps. (See diagrams near end of article.)

Note: The finely divided lead, frequently referred to as Pyrophoric lead, is prepared beforehand by the decomposition of lead tartrate (C.P.). Five to eight grams of lead tartrate are heated in a hard glass test tube (Pyrex) until all of the white tartrate is decomposed into finely divided lead (black). Corks to fit the tubes are soaked in hot wax to prepare them for sealing. The corks are inserted in the test tubes and the wax allowed to cool and harden. Extreme care should be taken to prevent leaks if the lead is to be stored for any length of time. Caution: It would be wise to heat the tartrate in a hood—or if none is available—a well ventilated room. The lead may be made immediately before using, but the dramatic effect of the experiment is lost if the experiment is shown immediately after being removed from a burner.

1. Show the wax-sealed test tube containing the finely divided lead.

a. This lead has a tendency to cake in the tube. Hence, shake it carefully to break up the material before sprinkling on floor.

b. Students may examine the lead in the sealed test tube.

2. Stand on raised platform or chair (achieving greater height for lead particles); uncork test tube and gently sprinkle lead to floor. (Caution: If lead is prepared ahead of class time and stored, it is wise to have a couple of spare tube set-ups in case the first does not illustrate the demonstration.)

Result: The lead should burst into flame as it falls toward the floor.

III. Recall other illustrations or past experiences where the same principle seems to apply.

1. Ask the class what this demonstration reminds them of. What have they seen that is like what happened in this demonstration? Allow time for two or three short responses.

2. Mention the following items as being related to what happened in this demonstration.

a. Proper mastication of food to enable digestive enzymes to contact food particles.

b. Cite danger of explosions in flour mills, lumber mills and dusty coal mines.

c. Recall that most explosive powder plants are thoroughly air-conditioned for safety.

d. Cite danger of entering dusty atmosphere with cigarette, cigar or pipe in enclosed structures.

IV. Pass out the tests and score sheets. Have the students do the test answering all questions on the score sheets as directed. All of the ten tests will be answered on the same score sheet so handle it carefully.

V. Collect the score sheets.

VI. Read the correct answers to the students.

106 — 3	109 — 1	112 — 3	115 — 2
107 — 1	110 — 4	113 — 2	116 — 2
108 — 3	111 — 5	114 — 5	117 — 1

VII. Further use of the instrument.

1. For the control group have no further discussion.

2. For the experimental group, use the instrument in every way possible to teach what is the scientific method and how one uses it. Do not bore the students with a prolonged discussion.

a. Stimulate discussion about the responses. Show why the correct responses are correct; why the others are not acceptable.

b. Show students wherein they have used the scientific method in arriving at their conclusions. Tell them that: In the preliminary discussion and demonstration you were faced with a problem; you observed certain facts.

In the test you were asked to pick out the facts, to select hypotheses to explain the facts and to arrive at a satisfactory conclusion. In questions:

106 and 107 you were checked on your observations.

108 you select the best hypothesis to explain what happens.

109 to 113 you test the different hypotheses by checking them against facts. A hypothesis must be in agreement with all known facts to be acceptable.

114 you check on the assumptions you have made.

115 you are concerned with new questions that arise.

116 you check on the assumptions that are made in applying the correct conclusion.

117 you apply the correct conclusion.

c. Help students with the new and difficult vocabulary.

d. Perhaps work out a mathematical problem showing tremendous increase of total surface area of a small solid by grinding it into smaller particles.

VIII. Historical background or other background material which may or may not be of interest.

Since reactions take place between molecules or atoms, and only when they collide, any factor which increases the number of collisions between the molecules or atoms of the reacting substances will increase the speed of reaction. Collisions can occur only at the surface of solid particles; by pulverizing the material the surface is greatly increased. By reducing to the colloidal state, the surface area is further increased. When in solution each particle is a separate molecule so presents a maximum of surface area.

The number of collisions can also be increased by increasing the temperature, which increases the rate of motion and hence the number of collisions. For each increase of 10° C. the rate of reaction doubles approximately.

STUDENT TEST NO. 4 ENTITLED WHAT HAPPENS WHEN FINELY DIVIDED LEAD IS EXPOSED TO AIR?

Write the date *in ink* on the score sheet just above the numbers of the questions that you will answer.

Answer all questions *in ink* on the score sheet. Draw a line between the two dotted lines on the score sheet which correspond to each correct response on the test. Draw but one line for each question. For example, you would answer item 150 by drawing a line between the dotted lines on the score sheet for item 150 as illustrated.

150. Check the number which is the sum of 5 and 3.

		1	2	3	4	5
1.	15	. .	. .	.|.	. .	. .
2.	2	. .	. .	.|.	. .	. .
3.	8	. .	. .	.|.	. .	. .
4.	4	. .	. .	.|.	. .	. .
5.	10	. .	. .	.|.	. .	. .

106. Check the statement that tells what happened when a test tube was uncorked and finely divided lead was sprinkled from it.

1. The lead particles floated in mid-air and burst into flame.

2. The lead particles fell to the floor and the cork glowed a dull red color.

3. The lead particles burst into flame as they fell to the floor.

4. The lead particles fell to the floor and as they touched the floor, it started a fire.

5. The lead particles turned white as they fell to the floor.

107. Check the statement which best describes the demonstration.

1. A test tube of prepared finely divided lead, corked and wax sealed, was opened and sprinkled from the tube.

2. A test tube of an unstable lead compound, corked and wax sealed, was opened and thrown from the tube.

3. A test tube, loosely corked, containing lead oxide was uncorked and the contents dropped to the floor.

4. A test tube of prepared finely divided lead, corked and wax sealed, was ignited and thrown to the floor in flames.

5. A test tube containing a mixture of oxygen and lead, tightly corked, was opened and the lead was allowed to fall to the floor in flames.

108. Check the hypothesis which most adequately accounts for what happened to the falling lead particles.

1. The carbon dioxide of the atmosphere and the lead particles rubbed against each other and heat was formed due to the friction.

2. The glass test tube has lent some of its energy to the finely divided lead and it escapes in the form of a flame when the lead is sprinkled from the test tube.

3. The tremendous increase of surface due to the finely divided state of the lead caused it to oxidize rapidly and burst into flame.

4. A chain reaction was begun between the nitrogen of the air and the finely divided lead particles.

5. An increased proportion of oxygen in the upper air of the room lowers the kindling temperature of the lead particles.

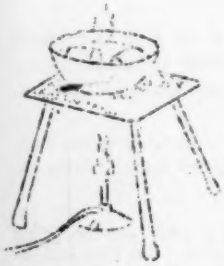
The hypothesis from questions 109 to 113 below which is in agreement with all known facts becomes a tentative conclusion concerning the way the finely divided lead is affected.

109. Check the fact which shows the first hypothesis to be unsound. (The carbon dioxide of the atmosphere and the lead particles rubbed against each other and heat was formed due to the friction.)

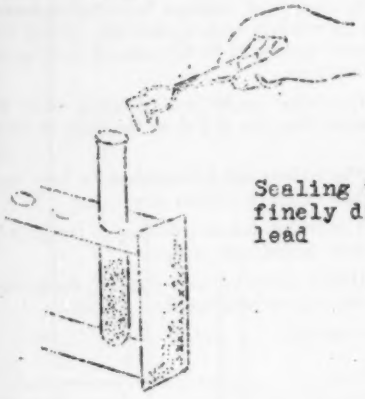
1. The friction between the molecules of carbon dioxide and the finely divided lead is not great enough to appreciably alter the temperature.

2. Carbon dioxide does not support combustion and hence does not act as an oxidizing agent.

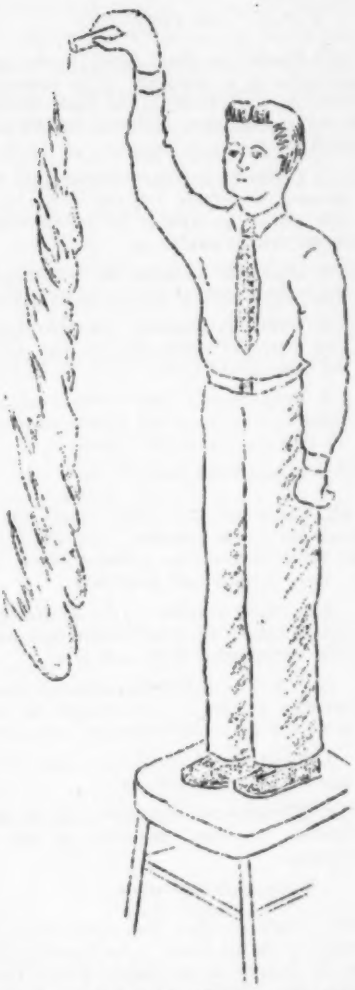
Heating hard glass test tube of lead tartrate to prepare finely divided lead



Soaking corks in hot wax



Sealing tube of finely divided lead



Finely divided lead bursting into flames as it is poured from the test tube

3. The carbon dioxide concentration in ordinary air is very low.

4. An insoluble substance is formed when carbon dioxide is mixed with lime water.

5. None of the above.

110. Check the fact which shows the second hypothesis to be unsound. (The glass test tube has lent some of its energy to the finely divided lead and it escapes in the form of a flame when the lead is sprinkled from the test tube.)

1. The energy possessed by the glass test tube is potential while the energy of the falling lead is kinetic.

2. Heat is always present when there is a transfer of energy.

3. Lead oxide has a rather low heat of formation.

4. Energy is not transferred between two objects unless there is evidence of a reaction between them.

5. None of the above.

111. Check the fact which shows the third hypothesis to be unsound. (The tremendous increase of surface due to the finely divided state of the lead caused it to oxidize rapidly and burst into flame.)

1. Oxidation reactions depend upon the total amount of surface exposed to the air, hence the smaller the exposed surface the slower will be the rate of oxidation.

2. Oxidation is, after all, dependent upon the amount of total surface to be oxidized.

3. Oxidation reactions proceed at a faster rate when the temperature is high than when the temperature is low.

4. Even though lead oxidizes readily, the metal is protected from further destruction by the thin lead oxide film formed.

5. None of the above.

112. Check the fact which shows the fourth hypothesis to be unsound. (A chain reaction was begun between the nitrogen of the air and the finely divided lead particles.)

1. A chain reaction might be likened to a billiard ball hitting other billiard balls and these balls hitting other balls, and so on.

2. A bolt of lightning sometimes causes the nitrogen of the air and oxygen to combine forming the unstable compound, nitrogen oxide.

3. Nitrogen and lead do not react chemically under ordinary conditions.

4. Nitrogen and hydrogen may be made to combine to form ammonia in the Haber Process.

5. None of the above.

113. Check the fact that shows the fifth hypothesis to be unsound. (An increased proportion of oxygen in the upper air of the room lowers the kindling temperature of the lead particles.)

1. An increase in the oxygen supply lowers the kindling temperature of a fuel.

2. At room temperature the different gases of the air mix thoroughly.

3. Oxidation reactions proceed at a faster rate when the concentration of the reacting substances is increased.

4. Oxidation reactions proceed at a faster rate when the temperature is increased.

5. None of the above.

114. You have discovered how finely divided lead will burst into flames when exposed to the air. Check the assumption listed below which you may disregard in drawing the correct conclusion.

1. The lead combined with oxygen to form lead oxide.

2. The same results would occur if the experiment were repeated.

3. Lead oxide has a rather low heat of formation.

4. The so-called facts listed above are facts.

5. The finely divided lead in the tube could not have been sub-divided further.

115. Check the question that would not logically be raised in connection with this demonstration.

1. Would the finely divided lead burst into flame as readily if it were further sub-divided?

2. Would the result be the same if a smaller test tube were used?

3. Would the result be the same if the finely divided lead was not chemically pure?

4. Would finely divided lead oxidize in air with but 10% oxygen?

5. Would the result be the same if the finely divided lead were dropped a longer distance to the floor?

116. A room in a flour mill was becoming heavily laden with wheat dust. The foreman immediately opened all windows for ventilation and warned all workers against smoking. Check the assumption that would be disregarded in applying your conclusion.

1. Oxidation would have the same effect on the wheat dust that it had on the finely divided lead.

2. The room could be considered a huge test tube full of finely divided wheat dust.

3. The wheat particles floating in the air are intimately mixed with oxygen.

4. Wheat particles and equally sized lead particles oxidize at about the same rate.

5. Oxidation is a surface-effect.

117. John was working in his chemistry laboratory and decided to make some iron sulfide by mixing iron and sulfur and heating the mixture. From his knowledge of chemistry, he decided to use finely divided iron and flowers of sulfur (finely divided sulfur) instead of a lump of iron and a lump of sulfur. Check the statement below which best describes his choice of the finely divided material.

1. Since the rate of chemical reaction depends upon the total amount of surface involved,

better results are obtained by using materials having large surface areas.

2. The rate of a chemical reaction increases with an increase in temperature.

3. The mixture will heat more uniformly if finely pulverized.

4. Less oxygen is present in a finely pulverized mixture of iron and sulfur.

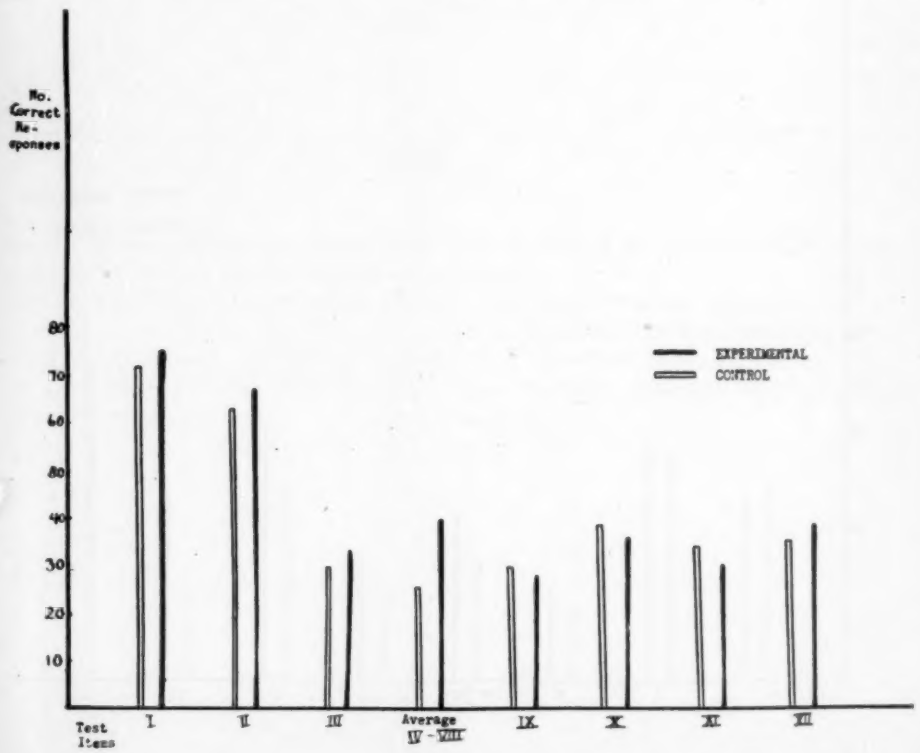
5. The iron sulfide is more uniform in color and texture if finely divided material is used.

ACCUMULATION AND TREATMENT OF DATA

Some of the teachers using the instruments will give them in reverse order. The control groups will take only the first two and the last two instruments with no analysis whatsoever. The experimental groups will do all of the instruments and there will be a careful analysis of the instruments. Comparisons will be made between the results obtained on each item by the control and experimental groups. It should be possible to determine if there are significant gains made by the experimental groups over those made by the control groups. Though I have received returns from but a few of the teachers, one is sufficiently complete to indicate what may be expected as the work is completed in other cases.

This case is a comparison of an experimental group of 39 ninth-grade pupils with a similar control group of 39 pupils using the general science instruments. When the total scores of these groups were plotted

A COMPARISON OF THE TOTAL NUMBER OF CORRECT RESPONSES MADE BY THE EXPERIMENTAL AND CONTROL GROUPS ON EACH ITEM OF THE FIRST TWO GENERAL SCIENCE TESTS



in a scattergram along with their intelligence quotients, a reasonably close agreement was obtained.

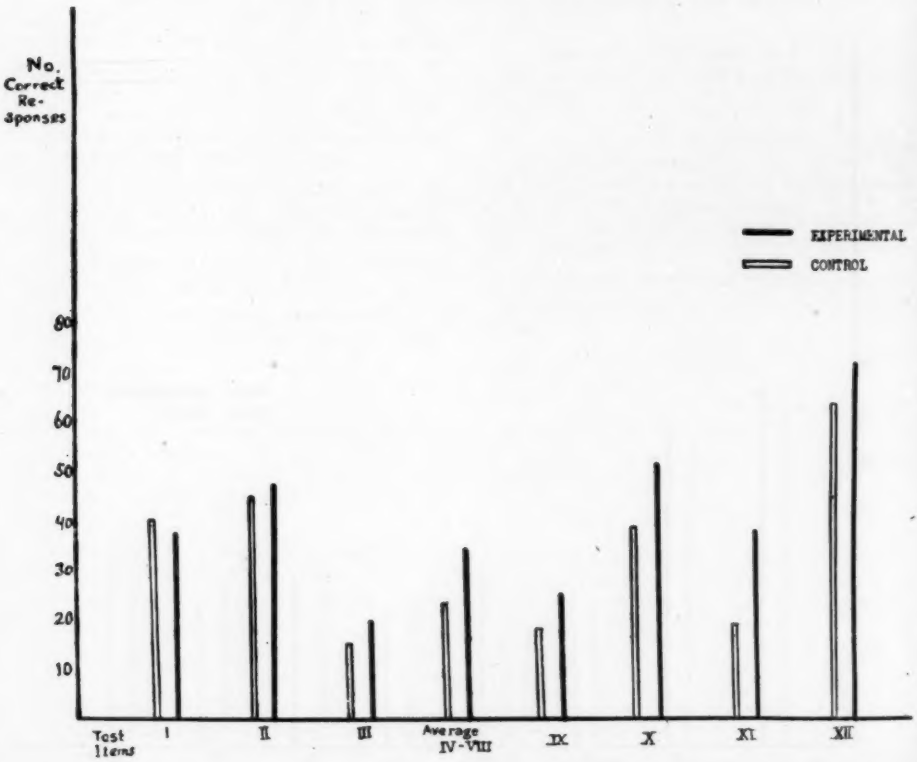
When the scores made by the experimental group on each of the test items of the first two instruments are compared with those made by the control group there is little difference as is shown by the first bar graph.

When a similar comparison is made between the experimental and control groups on the test items of the last two tests it is seen that on test items 9, 10, 11, and 12 the experimental group surpasses the control group.

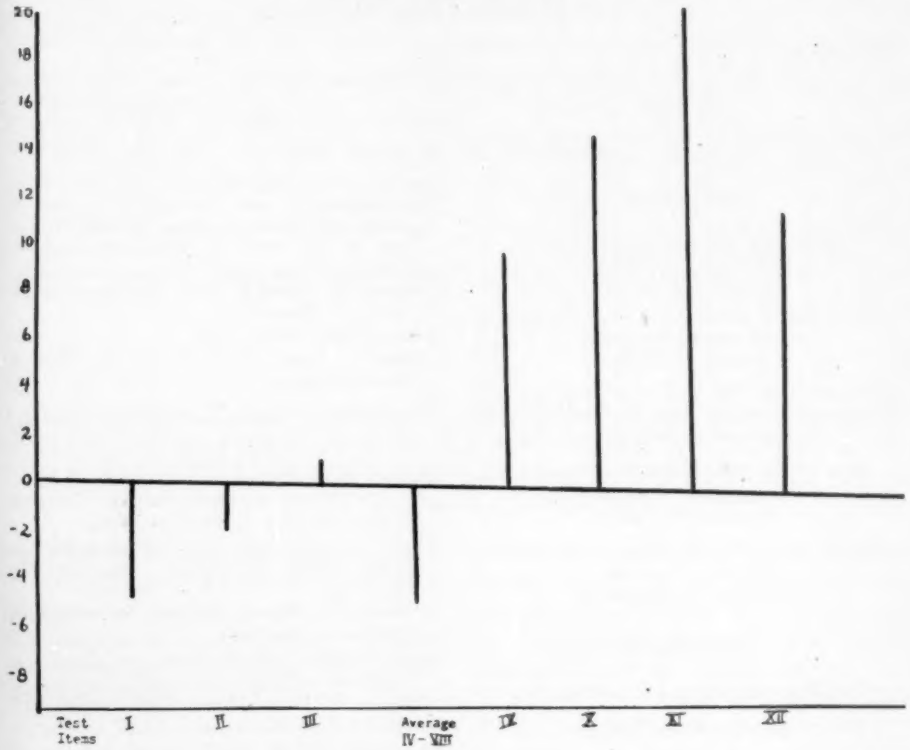
This comparison is clearer when the advantage procured by the experimental group over the control group in the first two tests is subtracted from that in the last two tests. This advantage is shown in the third bar graph.

In this preliminary analysis, the experimental group showed no advantage over the control group in those questions that asked what happened in the demonstration, in the selection of the correct hypothesis, or in the testing of the hypothesis with additional facts. But in the remaining items they proved superior. That is, they were better able to recognize the assumptions that underlie their conclusions; they could discern which questions would logically arise in connection with a particular demonstration; they were better able to recog-

A COMPARISON OF THE TOTAL NUMBER OF CORRECT RESPONSES MADE BY THE EXPERIMENTAL AND CONTROL GROUPS ON EACH ITEM OF THE LAST TWO GENERAL SCIENCE TESTS



GAINS MADE BY THE EXPERIMENTAL GROUP OVER THOSE MADE BY THE CONTROL GROUP WHEN THE SCORES MADE ON EACH ITEM OF THE LAST TWO TESTS ARE COMPARED WITH THOSE MADE ON THE FIRST TWO TESTS



nize the assumptions that one makes when applying the correct conclusion, and they were more skilful in making a direct application of the conclusion. It will be necessary to analyze many more results before one can say with certainty what advantage, if any, is to be gained by the use of instruments such as the ones described in this paper.

One result even now apparent is the interest of the teachers using the instruments. Their statements show that this procedure has markedly affected their teaching method.

PROGRAM OF TWENTY-SECOND ANNUAL MEETING OF THE NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

Hotel McAlpin, New York, New York

FEBRUARY 13, 14, and 15, 1949

OFFICERS

JOE YOUNG WEST, *President*
State Teachers College
Towson, Maryland

N. ELDRED BINGHAM, *Vice-President*
Northwestern University
Evanston, Illinois

CLARENCE M. PRUITT, *Secretary-Treasurer*
Oklahoma Agricultural and Mechanical College
Stillwater, Oklahoma

IRA C. DAVIS, *Executive Committee*
University of Wisconsin
Madison, Wisconsin

BETTY LOCKWOOD, *Executive Committee*
Harvard University
Cambridge, Massachusetts

PROGRAM

Sunday, February 13, 6:00 p. m.

Blue and Green Room

Reception and Annual Banquet

Monday, February 14, 9:00 a.m.

East Room

Report of Cooperative Committee

Report of Elementary Science Committee
Glenn O. Blough, U. S. Office of Education, Washington, D. C.

Report of Junior College Committee
William C. Van Deventer, Stephens College, Columbia, Missouri.

A Study of Science in General Education at the College Level.
Robert A. Bullington, MacMurray College, Jacksonville, Illinois.

A Course of Study in Economic Zoology for Students in Agriculture in Virginia Polytechnic Institute.
Cecil F. De LaBarre, Virginia Polytechnic Institute, Blacksburg, Virginia.

A Student Teaching Program Designed to Bridge the Gap Between Theory and Practice.
Raymond L. Walters, Plymouth Teachers College, Plymouth, New Hampshire.

The Construction and Validation of a Test to Measure Certain Aspects of Scientific Thinking in the Area of First Year College Physics.
Gordon M. Dunning, State Teachers College, Indiana, Pennsylvania.

A Non-Verbal Science Test.
John G. Read, Boston University, Boston, Massachusetts.

Monday, February 14, 2:00 p. m

East Room

Interests and Culture.
E. A. Sarhan, Teachers College, Columbia University, New York, New York.

Science Teachers' Objectives and Attitudes Toward Using Community Resources in Teaching.
Thomas P. Fraser, Morgan State College, Baltimore, Maryland.

Critical Selection and Evaluation of Enrichment Methods in Junior High School Science.
Lincoln F. Baar, Junior High School 117, Bronx, New York.

Evaluating Ability to Recognize Degrees of Cause and Effect Relationships.
William B. Reiner, New Utrecht High School, Brooklyn, New York.

The Scientist in the Making: Some Data and Implications from the Junior Scientists Assemblies.
Herbert S. Zim, Port Washington, New York.

Report of Junior High School Committee.
Earl R. Glenn, State Teachers College, Montclair, New Jersey.

Report of Senior High School Committee.
N. Eldred Bingham, Northwestern University, Evanston, Illinois.
J. Darrell Barnard, New York University, New York, New York.

Tuesday Morning, February 15

Guests of Bronx High School of Science

Tuesday, February 15, 2:00 p. m.

El Patio Room

One Hundred Interviews with Elementary School Teachers Concerning Science Education.
Theresa J. Lammers, State Teachers College, Westfield, Massachusetts

The Relative Achievements of the Objectives of Secondary School Science in a Representative Sampling of Fifty-Six Minnesota Schools.
Kenneth E. Anderson, University of Kansas, Lawrence, Kansas.

Supplementary Contributions of Sound Motion Pictures in High School Biology.
Harold E. Wise, University of Nebraska, Lincoln, Nebraska.

A Determination of the Relative Effectiveness of Sound Motion Pictures and Equivalent Teacher Demonstrations in Ninth Grade General Science.
Herbert A. Smith, University of Nebraska, Lincoln, Nebraska.

A Determination of Principles and Experiments for an integrated Course of Physical Science for High School.
Vaden W. Miles, Wayne University, Detroit, Michigan.

Some Implications of a Study on Science Teaching Conditions in New York State.
Paul F. Brandwein, Forest Hills High School, Forest Hills, New York.

Science Course Offerings and Facilities in Teachers Colleges of the United States.
Ellis Haworth, Wilson Teachers College, Washington, D. C.

Developing Physical Science Experiences Through the Use of Cooperative Group Processes.
Thomas J. Blisard, Newark College of Engineering, Newark, New Jersey.

OFFICIAL MINUTES OF THE BUSINESS MEETING OF THE NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING, SUNDAY EVENING, FEBRUARY 13, 1949, BLUE AND GREEN ROOM, McALPIN HOTEL, NEW YORK, NEW YORK.

At the close of the annual dinner meeting, President Joe Young West asked each member present to rise and indicate his teaching or other position. Members responding were: Joe Young West, Morris Meister, Martin L. Robertson, Julian Greenlee, Elsa Meder, William Reiner, Alfred D. Beck, Harry H. Williams, H. Emmett Brown, Charles W. Reynolds, Benjamin C. Gruenberg, Mervin E. Oakes, W. W. E. Blanchet, Zachariah Subarsky, Jerome Metzner, Philip G. Johnson, Don Decker, Lee R. Yothers, Richard H. Lampkin, Archie MacLean, Robert A. Bullington, Ellis Haworth, Hubert M. Evans, Raymond L. Walters, Elwood D. Heiss, Katharine Hill, Rose Lammel, J. Darrell Barnard, Herbert S. Zim, Kenneth E. Anderson, Paul F. Brandwein, George G. Mallinson, Harold E. Wise, Nathan A. Neal, Robert H. Carleton, Charlotte V. Meeting, Mary Alice Burmester, Earl R. Glenn, N. Eldred Bingham, Vaden W. Miles, William C. Van Deventer, Theresa J. Lammers, Gerald S. Craig, Betty Lockwood, and Clarence M. Pruitt.

The annual business meeting then proceeded as follows:

The official minutes of the last business meeting which was held at Atlantic City February 22, 1948, and were published in the April, 1948, issue of SCIENCE EDUCATION were approved as published.

The report of the Auditing Committee of the Treasurer's book was made for the committee by Gerald S. Craig. Other members of the committee were Martin L. Robertson and Elwood D. Heiss. The report stated the Treasurer's books had been audited and found to be in balance. The report was accepted.

Treasurer Clarence M. Pruitt presented each member with a mimeographed statement showing the financial status of The National Association for Research in Science Teaching. It was moved and seconded that the Treasurer's report be accepted. The motion carried.

The following new members were reported by the Secretary as recently having been elected to membership in The National Association for Research in Science Teaching by mail vote of the members:

Theresa J. Lammers, Richard H. Lampkin, Lee R. Yothers, Vernon C. Lingren, George T. Davis, Charles Wesley

Hoffman, Fletcher Guard Watson, and Oreon Keeslar. A committee was appointed to restudy the question of requirements for eligibility for membership in The National Association for Research in Science Teaching and for working out a more satisfactory nomination's blank for proposed new members. Members of this committee with the first named serving as chairman are: H. Emmet Brown, Earl R. Glenn, Francis D. Curtis, and Paul Blackwood. This committee is to make its report at the next annual meeting.

Doctor Morris Meister personally invited each member of the Association to visit the Bronx High School of Science on Tuesday morning, February 15. He outlined an interesting schedule for the visit and gave directions for members to reach the Bronx High School of Science by Subway.

Doctor N. Eldred Bingham made the Publications Committee Report. Members of the committee held a meeting in Chicago to pass upon the publication possibilities of the papers presented at the 1948 Atlantic City meeting. Other members of the committee were Charlotte L. Grant and Wilbur L. Beauchamp.

A questionnaire on regional meetings was given each member and each member was asked to indicate his preference. After some discussion on the problems of regional meetings, Doctor William C. Van Deventer was appointed to make a report of the findings at the business meeting before the close of the New York conference.

A motion was made by Clarence M. Pruitt that Doctor Benjamin C. Gruenberg be made an Honorary Life Member of The National Association for Research in Science Teaching. The motion was carried.

A report by the Advisory Committee working with the U. S. Office of Education was made by Philip G. Johnson. Members of the committee are William C. Van Deventer, Milton O. Pella, Earl R. Glenn, Francis D. Curtis, Arthur O. Baker, and G. P. Cahoon.

Professor Earl R. Glenn discussed at some length the work of his Junior High School Committee. He especially emphasized the need for making available in some abbreviated form the many research studies (particularly master and doctoral studies) that had been carried out in the Junior High School and other science teaching levels. A tentative plan and outline was presented by which members of his committee proposed to abstract a large number of such studies. Comments were made by Craig, Barnard, Johnson, Robertson, Brown, Brandwein, Anderson, Van Deventer, Pruitt, Mallinson, Miles, and Gruenberg. A motion was made by Barnard that the National Association for Research in Science Teaching make available to the Junior High School Committee the sum of two-hundred and fifty dollars ($250.00) for carrying out the proposed program of the committee. The motion was seconded by Van Deventer and upon vote, was declared passed.

Doctor Ellis Haworth moved that the Executive Committee be empowered to confer with members of the various committees with the idea of coordinating and simplifying the work of the several committees. The motion was seconded by Oakes. The motion was carried.

The report of the Nominating Committee was made by H. Emmett Brown. Other members of the committee were Don Decker and Glenn O. Blough. The report was as follows:

President: N. Eldred Bingham
Vice-President: Betty Lockwood
Secretary-Treasurer: Clarence M. Pruitt
Executive Committee: Joe Young West
Harold E. Wise

It was moved and seconded that the Secretary be empowered to cast an unanimous ballot for those named by the Nominating Committee. The motion carried.

The appointment of Vaden Miles to replace N. Eldred Bingham on the Publications Committee was made.

The program was carried out as indicated in the official program with one exception. The Cahoon report was read by Wise. At a brief business meeting Van Deventer made a report for the Regional Committee. The consensus of this report was that the National Association for Research in Science Teaching should hold its annual meeting, as in the past, at the time and place of the meeting of the American Association of School Administrators in years in which the AASA meets as a single group. Meetings in other years should be left to the discretion of the Executive Committee. It was thought advisable for NARST to hold one or more regional meetings during the year at the discretion of the Executive Committee. However the business meetings should be held at the time and place of the annual meeting rather than at some regional meeting. A motion was made and carried that the report be accepted.

At an Executive Committee meeting on Tuesday, February 15, the following committees were continued or revised as follows: Elementary Science, Glenn O. Blough, U. S. Office of Education, Washington, D. C., Chairman; Junior High School Science, Earl R. Glenn, New Jersey State Teachers College, Montclair, New Jersey, Chairman; Senior High School Science, J. Darrell Barnard, New York University, New York, New York, Chairman; Junior College Science, William C. Van Deventer, Stephens College, Columbia, Missouri, Chairman; Teacher Education, Dr. Katherine E. Hill, Wheelock College, Boston, Massachusetts, Elementary School, Chairman, and Clarence M. Pruitt, Oklahoma A and M College, Stillwater, Oklahoma, Secondary School, Chairman.

It was voted to extend a vote of thanks and appreciation to Doctor Morris Meister, Principal of the Bronx High School of Science, and his staff for the courtesies extended the association members as guests of the Bronx High School of Science. Everything possible was done to make the visit both enjoyable and educational.

Doctor George G. Mallinson was appointed to represent the NARST on the Cooperative Committee.

Respectfully submitted,
Clarence M. Pruitt
Secretary

NATIONAL COUNCIL OF ELEMENTARY SCIENCE OFFICERS ELECTED AT NEW YORK CITY MEETING

President: Glenn O. Blough, U. S. Office of Education, Washington, D. C.

First Vice-President: H. Emmett Brown, State Teachers College, Buffalo, New York

Second Vice-President: Mrs. Helen D. MacCracken, Estes Park, Colorado.

Secretary-Treasurer: Robert K. Wickware, Willimantic State Teachers' College, Willimantic, Connecticut.

Board of Directors: Robert Cooper (1949–1954), Ball State Teachers College, Muncie, Indiana; Katherine E. Hill (1949–1953), Wheelock College, Boston, Massachusetts; Clarence M. Pruitt (1949–1952), Oklahoma A. & M. College, Stillwater, Oklahoma; Florence G. Billig (1949–1951), Wayne University, Detroit, Michigan; Ruth G. Scribner (1949–1950), Minneapolis Public Schools, Minneapolis, Minnesota.

NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

FINANCIAL REPORT

February 12, 1949

RECEIPTS

Balance on deposit	$1570.30
Membership Fees	715.00
Total	$2285.30

EXPENDITURES

Science Education	$ 660.00
Secretary Expenses	100.00
Secretary-Treasurer's Bond	10.00
Hinkel Printing Company—Programs	22.74
G. P. Cahoon (Transportation costs to Cooperative Meeting)	35.99
Ira C. Davis—Expenses as President	12.00
Earl R. Glenn—Junior High School Science Committee	28.65
William C. Van Deventer—Junior College Committee	40.00
Glenn reprints	17.00
Van Deventer reprints	9.05
Bank Charges	4.62
Total	$ 940.05
Assets	$1345.25

Respectfully submitted

CLARENCE M. PRUITT,
Secretary-Treasurer

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